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Physical activity, exercise and the pelvic floor

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PALAVRAS-CHAVE: INTRA-ABDOMINAL PRESSURE; PELVIC FLOOR MUSCLES; PHYSICAL ACTIVITY; PHYSICAL EXERCISE; PREVALENCE; RISK FACTORS; STRESS URINARY INCONTINENCE.

“Everybody has a plan until they get punched in the face”

Mike Tyson

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Resumo

A incontinência urinária (IU) é uma disfunção prevalente em atletas do sexo feminino. A atividade física (AF) intensa tem sido identificada como um fator de risco para a IU, enquanto a AF moderada parece ter um efeito protetor. Contudo, o impacto de diferentes níveis de AF nos músculos do pavimento pélvico (MPP) tem sido pouco investigado. O objetivo desta tese foi analisar a prevalência da IU em atletas portuguesas de alta competição e identificar os seus potenciais fatores de risco. Pretendeu-se ainda analisar a associação entre o nível de AF e variáveis da função dos MPP. Foram efetuados 3 estudos transversais, em mulheres jovens e saudáveis com diferentes níveis de AF. Os dados foram recolhidos através de questionários, excepto os relativos às variáveis da função dos MPP tendo sido avaliadas através de manometria. Foi efetuada a análise estatística adequada aos objetivos em estudo, com ajuste para potenciais variáveis de confundimento. No estudo I, avaliou-se a prevalência e os fatores de risco da IU em 372 atletas de diferentes desportos e 372 controlos. No estudo II, investigou-se a associação dos Distúrbios Alimentares (DA) com a IU na mesma amostra. No estudo III, explorou-se a associação de diferentes níveis de AF com as variáveis da função dos MPP. Os resultados mostraram que: as atletas de alta competição apresentam um *odds* superior de IU em comparação com os controlos; as atletas com DA apresentaram maior probabilidade de IU de qualquer tipo, relativamente às atletas sem DA; o nível de AF associou-se com a pressão vaginal em repouso mas não com a força e a endurance dos MPP. Em conclusão, as atletas de alta competição apresentaram maior probabilidade de apresentar IU, sendo o risco aumentado naquelas que apresentaram DA. A AF em geral parece ser insuficiente para se obter um efeito de treino na força e na endurance dos MPP.

PALAVRAS-CHAVE: PRESSÃO INTRA-ABDOMINAL; MÚSCULOS DO PAVIMENTO PÉLVICO; ATIVIDADE FÍSICA; PREVALÊNCIA; FATORES DE RISCO; INCONTINÊNCIA URINÁRIA DE ESFORÇO; EXERCÍCIO FÍSICO

Abstract

Urinary incontinence (UI) is a prevalent dysfunction reported by female athletes. Strenuous physical activity (PA) has been identified as a risk factor for UI, whereas moderate PA seems to have a protective effect. However, the impact of different levels of PA on pelvic floor muscle (PFM) function has been scarcely investigated. The aim of this thesis was to assess the prevalence of UI in Portuguese elite female athletes and to identify its potential risk factors. Also, it aimed to clarify the association between PA level and variables of PFM function. Three cross-sectional studies were developed among young and healthy women with different levels of PA. All data were collected by questionnaires, except variables of PFM function that were assessed by manometry. Appropriate statistical analyses were performed, controlling for potential confounders. Study I assessed the prevalence and risk factors for UI among 372 elite athletes from different sports and 372 controls. The association of disordered eating (DE) and UI was assessed in Study II, in the same sample. In Study III, association of different levels of PA and variables of PFM function was explored. The results showed that the odds of UI was three times higher in elite athletes than in controls. Athletes with DE presented increased odds of UI of any type, in comparison to athletes without DE. PA was associated with vaginal resting pressure but not with PFM strength or endurance. In conclusion, athletes competing at elite level are at higher risk for UI than non-athletes, and DE behaviours may increase the risk for UI. General PA seems to be insufficient to achieve a training effect on PFM strength and endurance.

KEY-WORDS: INTRA-ABDOMINAL PRESSURE; PELVIC FLOOR MUSCLES; PHYSICAL ACTIVITY; PHYSICAL EXERCISE; PREVALENCE; RISK FACTORS; STRESS URINARY INCONTINENCE.

List of Abbreviations

ACSM American College of Sports Medicine

adjOR adjusted odds ratio

AG athlete group

BMI body mass index

CG control group

CIs confidence intervals

EDE-Q Eating Disorder Examination-Questionnaire

IAP intra-abdominal pressure

ICIQ-UI-SF International Consultation on Incontinence Questionnaire – Urinary Incontinence – Short Form

ICS International Continence Society

IPAQ-SF

IQR Interquartile range

IUGA International Urogynecological Association

LA *Levator ani*

MET Metabolic expenditure task

Min/wk minute/week

MUI mixed urinary incontinence

MVC maximal voluntary contraction

NAG non-athlete group

OR odds ratio

PA physical activity

PFM pelvic floor muscles

PFMT pelvic floor muscle training

RCTs randomized controlled trials

SD standard deviation

SPSS statistical package for the social science

SUI stress urinary incontinence

UI urinary incontinence

UUI urgency urinary incontinence

VRP Vaginal resting pressure

CHAPTER I

Introduction

Introduction

In recent decades there has been increasing concern with health promotion and disease prevention. Along with this has been a growing popularity of engaging in regular, moderate intensity, physical activity (PA) for its physical and psychological benefits. Engaging in regular moderate intensity PA has psychological (White et al., 2017) and physical benefits (Warburton, Nicol, & Bredin, 2006). These include preventing and controlling several chronic disorders such as cardiovascular disease, obesity, hypertension, diabetes and osteoporosis (Warburton et al., 2006). There are increasing numbers of women who actively exercise for recreation or competition. As opposed to moderate intensity PA, more strenuous and high intensity activities may lead to adverse effects for the musculoskeletal system, including the pelvic floor (Hunt et al., 2017; Joy, Van Hala & Cooper, 2009) (Panagodage Perera, Joseph, Kemp, & Finch, 2018). A concern regarding a possible harmful impact of strenuous activities and competitive sport participation on the pelvic floor has emerged from several reports of high prevalence of urinary incontinence (UI) in female athletes (Almeida et al., 2016; Eliasson, Edner, & Mattsson, 2008; Fozzatti et al., 2012; Vitton et al., 2011). Regarding the relationship between PA and UI, both leisure time activity and mild to moderate PA decreased the risk of having UI, whereas a lack of activity or strenuous exercise/heavy workload may increase the risk (Milson et al., 2016; Nygaard & Shaw, 2016).

PA is defined as “any bodily movement produced by the contraction of skeletal muscle that increases energy expenditure above a basal level” (Caspersen, Powell, & Christenson, 1985). It includes not only recreational and regular exercise training, but also PA during household tasks and other work-related and transport-related PA. The term exercise refers to PA that is planned, structured and repetitive (Caspersen et al., 1985). In the present work, the term exercising women refer to women who engage in any regular type of exercise or sport practice.

UI is defined by the International Continence Society (ICS) as “the complaint of any involuntary leakage of urine” (Haylen et al., 2010) and is the most common type of symptom attributed to a dysfunction of the pelvic floor muscles in women of all ages (Irwin et al., 2006), with a negative impact on quality of life (Chong, Khan & Anger, 2011) (Hampel et al., 2004). In adult women the most prevalent type of UI is stress urinary incontinence (SUI) (Irwin et al., 2006), which is associated with the “involuntary loss of urine on effort or physical exertion, or on sneezing or coughing” (Haylen et al., 2010).

Previous epidemiologic studies from the general population reported prevalence rates of UI in young women ranging from 6% to 12.4% (Al-Mukhtar, Akervall, Milson & Gyhagen, 2017; Bardino, Di Martino, Ricci & Parazzini, 2015 ; Caylet et al., 2006; Irwin et al., 2006 ; Liu, Wang, Huang, Wu & Wu, 2014; Peyrat et al., 2002). SUI is the most common type of UI in females, with prevalence rates varying between 3% to 58.4% (Breda, Bosch & Kort, 2015; Irwin, Kopp, Agatep & Milsom, 2011) (McKenzie, Watson, Thompson & Briffa, 2016). Apart from cultural and demographics differences in the study populations, the use of different definitions and screening methods may explain the wide range of prevalence values. A conceptual model of causal factors for pelvic floor disorders, including UI, has been proposed by De Lancey **(**DeLancey, Kane Low, Miler, Patel, & Tumbarello, 2008). From a life-span perspective, causal factors were grouped in three domains: predisposing factors, inciting factors and intervening factors. Factors influencing pelvic floor development such as genetics (Hannestad, Rortveit, Daltveit, & Hunskaar, 2003), nutrition (Thomas, Erdman, & Burke, 2016) and environmental factors (Altman, Forsman, Falconer; & Lichtenstein, 2008) are considered predisposing factors. Inciting factors include events such as, obstetric interventions (Hampel et al., 2004). Parity (Rortveit, Hannestad, Daltveit & Hunskaar, 2001) and vaginal delivery (Rortveit, Daltveit, Hannestad & Hunskaar, 2003) are the main obstetric risk factors for UI in reproductive years. The latter may provoke potential damage of muscles and nerves of the pelvic floor and succeeding deliveries may have a cumulative effect. Intervening factors include: chronic constipation, which has been suggested as a risk factor for UI (Amselem et al., 2010) and may affect the pelvic floor load by increasing stress and strain over time (DeLancey et al., 2008); Obesity has been associated not only with prevalence but also with UI severity (Subak, Richter & Hunskaar, 2009), explained by the fact that obesity may stress the pelvic floor due to chronic increased IAP (Noblett, Jensen & Ostergard, 1997); generalized problems such as *diabetes mellitus*, neurological diseases and chronic bronchitis (Hampel et al., 2004).

Prevalence of UI among exercising women and associated risk factors

In the last two decades several studies have reported a high prevalence of overall UI and SUI in young and healthy exercising women (Bø, Bratland-Sanda, & Sundgot-Borgen, 2011; Da Roza, Brandão, Mascarenhas, Jorge, & Duarte, 2015a; Eliasson, Larsson, & Mattsson, 2002; Eliasson, Nordlander, Mattsson, Larson, & Hammarström, 2004; Eliasson et al., 2008; Jácome, Oliveira, Marques, & Sá-couto, 2011; Nygaard, Thompson, Svengalis, & Albright, 1994; Thyssen, Clevin, Olesen, & Lose, 2002). However, the presented rates vary depending on sport type, with the highest prevalence found in athletes performing intense and high-impact activities (Fozzatti et al., 2012; Hagovska, Švihra, Buková, Dračková & Švihrová, 2018; Vitton et al., 2011) such as running (Nygaard et al., 1994; Póswiata, Socha, & Opara, 2014) and jumping (Eliasson et al., 2008; Eliasson et al., 2002; Nygaard et al., 1994; Thyssen et al., 2002).

Each sport has specific physical demands and different athletic movements. A higher effect on the pelvic floor may be related to more dynamic movements and more impact from ground reaction forces. This may explain the wide difference of prevalence rates previously reported across sports types, varying between 0% in golf (Nygaard et al., 1994) and 80% in trampoline (Eliasson et al., 2002). However, when comparing the same sport between studies some controversial results have been found, such as prevalence rates between 4.3% and 44.4% in volleyball players (Almeida et al., 2016; Borin, Nunes, & Guirro, 2013; Thyssen et al., 2002) and 6% (Nygaard et al., 1994) to 84.6% (Almeida et al., 2016) in swimmers.

However, the demographic and risk factors correlated with sports practice are still under study. Strenuous work/exercise has been listed as a possible risk factor for UI / SUI (Milsom et al., 2016; Nygaard & Shaw, 2016) but it is not entirely clear how this predisposes exercise practitioner women engage in PA recreationally, or in competition. A better understanding of the impact of exercise on the pelvic floor muscles (PFM) function/dysfunction will be useful to develop strategies to prevent and treat SUI in young exercising women.

Epidemiological studies in Europe have demonstrated differences between countries (Hunskaar, Lose, Sykes & Voss, 2004), suggesting influences of cultural, genetic and environmental factors. Therefore, although strenuous activities have been suggested as increasing the risk of UI (Milson et al., 2016; Nygaard & Shaw, 2016), studies on athletes should include a control group to eliminate any possible non-exercise related confounders (Hunskaar et al., 2004).

Concerning exercise practice in general, some variables have been related to UI: volume of training (hours/week) (Da Roza, Brandão, Mascarenhas, Jorge, & Duarte, 2015b; Eliasson et al., 2008), exercise intensity (Nygaard et al., 1994; Vitton et al., 2011) competition level (Da Roza et al., 2015b; Simeone et al., 2010) and years of sport practice (Alanee, Heiner, Liu, & Monga, 2009; Eliasson et al., 2008; Eliasson et al., 2002).

At a high competition level the demands of improved performance are huge from both psychological (Schaal et al., 2011) and physical standpoints (O'Keefe et al., 2012). To achieve higher performance athletes must practice intensively, which may increase the risk of physical injury, biochemical changes and mental-emotional distress (Maffetone & Laursen, 2016). In order to optimize body size and composition for competitive success, athletes often suffer from abnormal disordered eating attitudes and behaviours such as restrictive eating, fasting, frequent meal skipping, use of diet pills, laxatives, diuretics, enemas, overeating, binge-eating and purging (Kong & Harris, 2015) (Nattiv et al., 2007). The topic of disordered eating among athletes, has been studied by many researchers in the last decade. Studies have found a higher prevalence of disordered eating among elite athletes than non-athletes (Kong & Harris, 2015; Martinsen & Sundgot-Borgen, 2013; Sundgot-Borgen & Torstveit, 2004; Thiemann et al., 2015) particularly among female athletes (Byrne & McLean, 2002; Sundgot-Borgen & Torstveit, 2004) and athletes competing in weight-sensitive sports (Kong & Harris, 2015; Sundgot-Borgen & Torstveit, 2004; Torstveit, Rosenvinge, & Sundgot-Borgen, 2008). In previous research, a higher prevalence of UI was found in athletes with disordered eating (Araújo et al., 2008; Bø & Borgen, 2001) suggesting an association between both conditions. However, they did not control for potential confounders and no conclusions could be drawn regarding such association.

A lack of proper nutrition in relation to the necessary intake of macro and micro-nutrients to support training and competition requirements has been reported previously in high-level female athletes from different sports, such as rhythmic gymnastics (Gibson, Stuart-Hill, Martin, & Gaul, 2011; Silva & Paiva, 2015), soccer (Gibson et al., 2011), high jumping (Bogdanis, Veligekas, Selima, Christofi & Pafili , 2013) volleyball, middle distance running, ballet dancing and swimming (Hassapidou & Manstrantoni, 2001). A low intake of carbohydrates and several key micro-nutrients such as vitamin B, D and E and minerals (calcium, iron, boron and magnesium) has been identified (Bogdanis et al., 2013; Gibson et al., 2011; Silva & Paiva, 2015). A suboptimal intake of carbohydrates can result in premature muscle glycogen depletion during training and competition, leading to muscle fatigue (Ørtenblad, Westerblad, & Nielsen, 2013). Regarding micro-nutrients, vitamin B is related to protein synthesis and tissue repair and maintenance and vitamin D is involved in the regulation of muscle contraction and nerve conduction (Thomas et al., 2016).

Hence, as skeletal muscles are critical components of the pelvic floor (DeLancey, 1994), nutritional status may affect PFM function. Despite the fact there are no studies on the effect of lack of nutrients on PFM function, a relationship between disordered eating and musculoskeletal injury has been reported (Rauh, Nichols, & Barrack, 2010; Thein-Nissenbaum, Rauh, Carr, Loud, & McGuine, 2012).

Another aspect that has been related to disordered eating is menstrual dysfunction (Nattiv et al., 2007) such as oligomenorrhea or amenorrhea and a decrease in oestrogen level may occur (Harlow, Windham, & paramsothy, 2013). Oestrogen receptors have been detected in the lower urinary tract and the surrounding tissues, suggesting that oestrogen may play a role in continence status (Söderberg et al., 2007; Xie et al., 2007). However, the association between oestrogens and UI remains controversial (Cody, Jacobs, Richardson, Moehrer, & Hextall, 2012).

Disordered eating can lead to energy deficiency (Melin et al., 2015). The inter-relation of energy deficiency, menstrual dysfunction and osteoporosis is called Female Athlete triad (Nattiv et al., 2007). Athletes may present low energy availability due to abnormal eating habits but also from excessive exercising and training without a concomitant change in eating habits to an adequate caloric intake relative to their exercise level (Byrne & McLean, 2002; Castelo-Branco, Reina, Montivero, Colodrón, & Vanrell , 2006; Hassapidou & Manstrantoni, 2001; Melin et al., 2015). The consequences of this triad can be devastating for the female athlete (Nattiv et al., 2007).

Physical activity/exercise, pelvic floor function and stress urinary incontinence

Any PA promotes a rise in IAP (Junginger, Baessler, Sapsford, & Hodges, 2010) which is modulated by the contractile structures surrounding the abdominal pelvic cavity, such as the abdominal muscles (Cresswell &

Thorstensson, 1989; Cresswell, 1993; Junginger et al., 2010; Sapsford & Hodges, 2001), the respiratory diaphragm (Hodges & Gandevia, 2000), the *erector spinae* muscles (Cresswell, 1993) and the PFM (Junginger et al., 2010). In an erect posture, the weight of the abdominal organs leads to an increase of IAP, pressing downwards on the pelvic structures (Shafik, El-Sharkawy, & Sharaf, 1997) and consequently further stressing the PFM. More strenuous and high-impact PA implies a greater increase in IAP (Shaw et al., 2014), and hence women who perform these type of activities may have an increased risk of damaging the PFM.

In relation to the effect of PA on the pelvic floor, two opposing hypotheses have been proposed. The first hypothesis postulates that females who perform intense activities may have strong PFM due to muscular pre-contraction. The second hypothesized that strenuous PA which increases IAP can overload and chronically damage the perineum structures, including the PFM, leading to UI (Bø, 2004).

The stress continence mechanism comprises the combined activity of different elements of the pelvic floor, including ligaments, fascia, smooth and striated muscles, each of which contribute to overall pelvic organ support and continence (DeLancey, 1994). In this sense, SUI may be a multifactorial condition that can develop as a result of one or more deficits of these pelvic structures, despite the fact that it appears that intact components can compensate for deficient ones, up to a threshold where symptoms of SUI occur (Weber et al., 2004).

The PFM are an important component of the continence mechanism. They comprise a set of muscles arranged in different layers and with different fibre directions that act as a single functional unit (Stoker, 2009). Ashton-Miller and colleages (Ashton-Miller, Howard, & DeLancey, 2001) presented a stress continence system divided into two parts: 1) urethral support system and 2) sphincter closure system. The striated muscles related to the urethral support are the *levator ani muscles* (LA), which comprised three parts, the pubococcygeus, the puborectalis and the iliococcygeus. The striated urethral sphincter muscle is related to the closure system (Ashton-Miller et al., 2001). A correct PFM contraction results in an inward and anterior movement of the urethra, vagina and rectum toward the pubic *symphysis* (Bø, Lilleås, Talseth, & Hedland , 2001; Bø et al., 2017). The PFM are composed of a higher proportion of Type I than Type II muscle fibres, of 70% *vs.* 30% respectively, with some variation between the muscles (DeLancey, 1994). The Type I or slow twitch fibres are involved in slower and prolonged contraction and are responsible for a constant muscular tone, while Type II or fast twitch fibres are responsible for a quick and strong contraction (Waterhouse, 2008).

Different aspects of PFM function such as strength, endurance, resting tone and neural control are important to provide both continence and organ support (DeLancey, 1994; Herschorn, 2004), and can be measured objectively with different tools (Bø & Sherburn, 2005). Quantification of PFM strength, endurance and resting tone can be assessed by digital palpation, manometry or dynamometry, and electric activity can be assessed by eletromyography with intramuscular or surface electrodes. Each tool presents advantages, disadvantages and limitations. An overview of this subject has been conducted by Bø & Sherburn (Bø & Sherburn, 2005).

Increased PA can improve overall body strength, which theoretically would have a positive effect on the performance of the PFM. However, its exact impact on the PFM has yet to be determined. Moreover, the literature is scarce on establishing a relationship between the impact of PA and objective measures of PFM function. A study comparing women engaged in strenuous and non-strenuous exercise found no significant differences in vaginal resting pressure (VRP) and PFM strength, nor pre or post-exercise condition (Middlekauff, Egger, Nygaard, & Shaw, 2016). On the contrary, lower PFM strength was found in athletes compared to controls (Borin et al., 2013). In a sample of young nulliparous women with SUI, a decrease in the maximum voluntary contraction after 90 min of strenuous exercise has been observed (Ree, Nygaard, & Bø, 2007)

A common measure of muscle strength is the strongest force that can be exerted by a group of muscles during a single maximum effort (Bø et al., 2017; Knuttgen & Kraemer, 1987). The strength of a muscle´s contraction depends on various factors including the number of stimulated fibers, the frequency of stimulation, the thickness of each muscle fiber and the initial muscle resting length (Waterhouse, 2008). An optimal normal resting length maximizes the ability of the muscle to contract and generate maximal strength. If the contraction begins when the muscle fibres are already stretched or shortened, the efficiency of contraction will be reduced (Close, 1972). This inter-relation between resting length and muscular contraction is referred to as the length-tension relationship. Studies related to this subject on the PFM are scarce. In this context it has been found that the active force measured by dynamometry varies at different vaginal apertures, suggesting that the rationale of the length-tension principle of skeletal muscle can be applied to the PFM (Morin, Bourbonnais, Gravel, Dumoulin, & Lemieux, 2004; Verelst & Leivseth, 2007). Stretched muscles may take too long to reach an optimal contraction to prevent descent against increased abdominal pressure (eg, sneeze), and so leakage can occur (Bø & Sherburn, 2005).

Contractions of urethral striated muscle fibres and the LA muscle are responsible for maintaining urethral closure during PA, and provide resistance to the downward displacement of the urethra and bladder neck during increased IAP (DeLancey, 1994). To prevent urine loss during an abrupt increase in IAP a fast and strong contraction of the PFM is needed (which implies recruiting Type II fibres) (Bø, Braekken, Majida, & Engh, 2009). However, the magnitude of abdominal forces generated by strenuous/intense PA imposed on the PFM may overcome the continence mechanism, leading to SUI.

Despite no significant difference in PFM strength having been found between continent and incontinent women by some authors (Bø & Stien, 1994; Da Roza, Mascarenhas, Araújo, Trindade, & Natal Jorge, 2013; Da Roza et al., 2015b; Madill, Harvey, & McLean, 2009; Morin et al., 2004; Verelst & Leivseth, 2004), others have reported weaker PFM in women with SUI when compared to controls (Amaro, Moreira, De Oliveira Orsi Gameiro, & Padovani, 2005; Chamochumbi, Nunes, Guirro & Guirro, 2012; Peng, Jones, Shishido, Omata, & Constantinou, 2007; Shishido, Peng, Jones, Omata, & Constantinou, 2008; Thompson, O´Sullivan, Briffa, & Neumann, 2006; Verelst & Leivseth, 2007). Nevertheless, muscle performance does not seem to be highly dependent on muscle morphology, with studies showing ticker PFM in both continent (Mørkved, Salvesen, Bø , & Eik-Nes, 2004) and incontinent (Da Roza et al., 2015). Further studies are needed in this area.

Pelvic floor muscle endurance is the ability to sustain a maximal static or isometric contraction, or the ability to repeatedly perform the maximum number of repetitions at a given percentage of the maximal force without getting tired (Bø et al., 2017). Therefore, good endurance is needed to maintain PA for longer periods without urine loss. Reduced PFM endurance may lead to impaired support for the pelvic and abdominal organs during prolonged activity. Over time, repetitive stress over the PFM and a bowl-shape of the pelvic floor may have long-term implications for UI (Thompson & O'Sullivan, 2003). Only a few studies evaluated PFM endurance, with different trends on the results, some of them showing differences (Burti, Hacad, Zambon, Polessi, & Almaida, 2015; Morin et al., 2004) and others describing no differences between continent women and those with SUI (Madill et al., 2009; Verelst & Leivseth, 2004).

Muscle tone can be viewed as the resistance to passive elongation and is dependent of contractile and viscoelastic components (Bø et al., 2017; Simons & Mense, 1998). Even in relaxed states, some of the PFM fibres (Type I) contract to produce a constant, slight, partial contraction that maintains muscle tone and keeps it ready to respond (Waterhouse, 2008), increasing or decreasing contraction as a function of changes in the IAP (Shafik, Doss, &

Assad, 2003). A proper muscle tone provides a constant and adequate support of the pelvic organs. A lower resting tone has been associated with prolapse of the anterior and posterior compartments (Dietz & Shek, 2008). Few authors measured PFM resting tone (VRP or resistance to elongation). While Morin and colleages (Morin et al., 2004) found higher passive force at elongation in continent women compared to those with SUI, the same trend was not observed by others (Chamochumbi et al., 2012; Verelst & Leivseth, 2007).

The results of PFM strength and endurance reported in the aforementioned studies demonstrate high variability values of PFM strength and endurance in both continent and incontinent women. As pointed out previously, the use of different tools, assessment protocols and sample characteristics may contribute to these findings. There are no established normative values for PFM strength, endurance and VRP. Hence, values obtained from PFM function measurements are difficult to interpret. Theoretically, if reference values for PFM function could be determined, it would allow determining the presence and extent of muscle weakness in both research and clinical settings.

Pelvic floor muscle neuromuscular control refers to the activation pattern of these muscles under different conditions. PFM are reflexively activated during limb movements (Hodges, Sapsford, & Pengel, 2007; Sjödahl, Kvist, Gutke, & Öberg, 2009) and other common activities such as valsalva manoeuvre (Junginger et al., 2010). Several researchers tried to identify and describe a normal pattern of PFM activity (Bø & Stien, 1994; Bø, Sherburn, & Allen 2003; Bø et al., 2009; Junginger et al., 2010; Madill et al., 2009; Neumann & Gill, 2002; Sapsford et al,, 2001; Sapsford & Hodges, 2001; Verelst & Leivseth, 2004). Regarding neuromuscular control, some studies in small samples with continent women found a co-activation of the abdominal muscles and the PFM, with a pattern of activity recruitment. Differences were reported between women with SUI and controls regarding PFM activation during functional activities (Deffieux et al., 2008; Madill et al., 2009; Madill, Harvey, & McLean, 2010; Moser, Leitner, Baeyens, & Radlinger , 2018; Neumann & Gill, 2002; Sapsford et al., 2001; Sapsford & Hodges, 2001; Smith, Coppieters, & Hodges, 2007), but to this date, the normal coordination pattern has not been established. Hence, the evidence to support the claim that SUI women have abnormal patterns of PFM activation is weak.

To date, there is scant knowledge about risk factors and several epidemiologic studies have been published on the prevalence of UI in elite athletes, who are those most exposed to high intensity sport practice. Few studies regarding the prevalence of UI in exercise practitioner Portuguese women and associated risk factors have been published. Moreover, little is known regarding the effects of PA/exercise on PFM function and by which mechanisms it can lead to UI. To date, no reference values and normal pattern of activation for PFM function have been established. Hence, there is a need to develop more studies in this field. Despite the high prevalence of disordered eating found in female athletes, few studies have addressed the association between disordered eating and UI. Also, these studies did not quantify the magnitude of this association and did not control potential confounders.

Hopefully, the present work will contribute to increasing knowledge about prevalence and risk factors associated with UI in Portuguese elite female athletes and an improved understanding of the impact of PA and physical exercise on young women's pelvic floor health, so as to improve strategies to deal with this silent dysfunction.

This Thesis is organized in five Chapters. Chapter I include this Introduction, which reviews the literature regarding the epidemiology of UI and corresponding risk factors, among which exercise practice assumes a particular importance. It also focused on the importance of different parameters of PFM function and their potential relation with SUI. At the end of the Introduction the overall and specific aims of the work developed for this PhD Thesis are defined. Chapter II includes three Original Studies, which were developed in order to respond to the specific Aims. Chapters III and IV correspond to the Integrated

Discussion and Conclusions, respectively. Chapter V gather Future Perspectives. The bibliography references that support the main concepts and findings are presented at the end of the Introduction and Integrated Discussion chapters.

AIMS

Aims

The overall aim of this thesis was to analyse the impact of different levels of PA and exercise on UI among young women.

The specific aims were:

1. To assess the prevalence of UI in Portuguese elite female athletes and age- matched controls and, identifying potential risk factors for UI (Study I).

2. To assess the prevalence of disordered eating in Portuguese elite female athletes and to analyse its association with UI (Study II).

3. To analyse the association betweem different levels of PA on different parameters related with PFM function, in women with and without SUI (Study III).

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CHAPTER II

Original Articles

Study I

Performing high-level sport is strongly associated with urinary incontinence in elite athletes: a comparative study of 372 elite female athletes and 372 controls

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ABSTRACT

Objective To evaluate the prevalence of urinary incontinence (UI) in female elite athletes compared with controls and to investigate potential risk factors for UI among elite athletes.

Methods This cross-sectional study included 372 elite athletes (AG) and 372 age-matched controls (CG). The median age was low (19 years) and the vast majority were nulliparous. Potential risk factors, including clinical, demographic, and sports practice characteristics, were collected by using a questionnaire. The International Consultation on Urinary Incontinence Questionnaire-Urinary Incontinence-Short Form was applied to estimate the prevalence of UI. Odds ratios (OR) with 95% confidence intervals (95%CI) were used to estimate the association with UI. The final model was adjusted for constipation, family history of UI and history of urinary infection.

Results The prevalence of UI was 29.6% and 13.4% in AG and CG, respectively ($p<0.001$). The following prevalences were obtained: AG: 19.6% and CG: 3.5%, ($p<0.001$) for stress UI, AG: 3.8% and CG: 5.4%, ($p=0.292$) for urgency UI, AG: 5.9% and CG: 0.8% ($p<0.001$) for mixed UI. After adjustment, performing high-level sport (adj OR=3.31; 95%CI 2.20-4.97), family history of UI (adj OR=1.54; 95% CI: 1.04-2.29), history of urinary infection (adj OR=1.53; 95% CI: 1.05-2.23) and constipation (adj OR=1.79; 95%CI 1.07-2.98) were associated with UI.

Conclusion The prevalence of UI among Portuguese female elite athletes is high and the odds of UI were 3 times higher than in controls. Also, constipation, family history of UI and history of urinary infections were significantly associated with UI.

Keywords: URINARY INCONTINENCE; FEMALE ELITE ATHLETES; PREVALENCE; RISK FACTORS

INTRODUCTION

Urinary incontinence (UI) is a common problem among females, with a negative impact on quality of life.[1,2] UI is defined as "the complaint of any involuntary leakage of urine".[3] Previous studies have reported that the prevalence rates of UI in young women ages 15 to 44 years in the general population range from 6.2% to 12.4%.[4-9] Stress urinary incontinence (SUI) is defined as "the complaint of involuntary loss of urine on effort or physical exertion, or on sneezing or coughing"[3] and is the most common type of female UI, with prevalence rates varying from 3% to 58.4%.[10] The wide variation in prevalence rates is explained by the different definitions used and populations studied.[11,12]

Although moderate physical activity has been reported to decrease the odds of having a risk of developing UI, strenuous work/exercise has been listed as a possible risk factor for the condition.[13,14] A systematic review by Bø[15] showed that the highest prevalence of UI during sports involved high-impact activities, such as gymnastics and ball games. Regarding the prevalence of UI in different sports, the rates vary between 0% in golf players[16] and 88.9% in artistic gymnastics and trampoline athletes.[17]

Two opposing hypotheses have been suggested regarding the effect of exercise on the pelvic floor muscles (PFM). One proposes that the increased impact of abdominal pressure and ground-reaction forces may lead to simultaneous or pre-contraction of the PFM, resulting in a training effect of the muscles. The other suggests that strenuous physical activity without simultaneous co-contraction of the PFM may overload, stretch, and weaken the pelvic floor.[15]

Till date, several risk factors for SUI in the general population have been identified such as vaginal birth, age, diabetes mellitus, obesity, recurrent urinary tract infections, neurological diseases and chronic bronchitis,[1] but few epidemiological studies on the prevalence and risk factors of UI in female elite athletes have been published.[18-21] Hence, the aim of the present study was to evaluate the prevalence of UI in female elite athletes of different sports compared with age-matched controls and to investigate possible risk factors for UI, including sports practice and anthropometric characteristics, in addition to medical history.

METHODS

This is a cross-sectional study of Portuguese female elite athletes. Data on the athletes were collected between November 2014 and October 2015, whereas data on a control group were collected between April 2015 and February 2016. Presidents of the larger national sports federations in Portugal were contacted by e-mail and asked to participate in the study. Five of 18 presidents did not respond. A total of 416 elite athletes were identified from the different sports federations. Of this number, the authors were able to contact 373 athletes, and 372 (89.4%) agreed to participate in the research. For comparison, a control group of 372 individuals was included. Controls were contacted in high schools, universities, malls and other public areas. Women were approached by one of the researcher (AC) and invited to participate in the study and, if they met the selection criterions, they full-fill the questionnaire. The participation rate was 92.5%. Matching procedure was performed in a 1:1 ratio, taking the year of birth as reference.

Female elite athletes ages 15-48 years who had been part of their respective national teams for at least one year and who had reached an international level of competition were included in the study. Age-matched controls were recruited from the general population. The exclusion criteria were pregnancy at the time of the study or during the last year, any illnesses, or inability to understand the Portuguese language. A specific exclusion criterion for the control participants was practice of exercise more than twice weekly.

Data were collected with the use of hand-delivered questionnaires. Each questionnaire was divided into three sections. Section 1 included data on general background variables, such as age, weight, height, and parity. Section

2 contained questions related to medical history, such as common illnesses, medications, constipation, urinary infection, family history of UI, gynaecologic and obstetric history, and whether UI had been reported to a physician. Section 3 covered questions on sports practice characteristics, such as type of sport, years of sports participation, and volume of training (hours/week). In addition, the athletes were asked about UI in relation to sports practice and, if present, whether this occurred during training and/or competition, as well as the impact of UI on sports performance and whether any type of protection was worn to prevent leakage.

UI was assessed by using the International Consultation on Incontinence Questionnaire-Urinary Incontinence-Short Form (ICIQ-UI-SF),[22] which is a reliable and valid questionnaire for assessing the prevalence, severity, impact on quality of life, and type of UI.[22] The ICIQ-UI-SF has been translated into Portuguese language, and its Portuguese translation has been validated.[23] The questionnaire includes three scored items. The first item asks: ‘‘How often do you leak urine?’’ (0, never; 1, about once a week or less often; 2, two or three times a week; 3, about once a day; 4, several times a day; and 5, all the time). The second item asks: ‘‘How much urine do you usually leak (whether you wear protection or not)?’’ (0, none; 2, a small amount; 4, a moderate amount; and 6, a large amount). The third item asks: ‘‘Overall, how much does leaking urine interfere with your everyday life?’’ (a visual analogue scale is used, ranging from 0, not at all, to 10, a great deal). A fourth non-scored item asks about the patient’s perception of the cause and type of leakage. UI was defined as any UI (one or more positive responses to the fourth question of ICIQ-UI-SF). Frequency of UI was assessed by the first item; the second item was used to evaluate amount of leakage and, the third item determined the overall impact of UI on quality of life. When the involuntary loss of urine was associated with coughing, sneezing, physical activity, or exercise, UI was classified as stress urinary incontinence (SUI). Involuntary loss of urine before reaching the toilet was classified as urgency urinary incontinence (UUI). Cases of both SUI and UUI were classified as mixed urinary incontinence (MUI). The remainder was classified as other types of UI.

The sports included in the present study were classified into seven groups as previously described,[19,24] (Table 1).

Table 1. Sports disciplines under the different sports groups and the corresponding number of participants

Sports disciplines	n	Sports group n	Sports group %	Sports group
Horse jumping	14	14	3.8	G1 Technical sports
Swimming	9	31	7.5	G2 Endurance sports
Middle-distance running	14			
Rowing	3			
Canoeing	5			
Figure roller skating	5	25	7.5	G3 Aesthetic sports
Synchronized swimming	11			
Acrobatic gymnastics	3			
Rhythmic gymnastics	6			
Karate	3	25	6.7	G4 Weight sports
Judo	21			
Weight lifting	1			
Soccer	35	252	67.7	G5 Ball Games sports
Indoor soccer	2			
Basketball	58			
Roller hockey	10			
Handball	30			
Volleyball	24			
Water polo	31			
Rugby	41			
Tennis	14			
Table tennis	5			
Paddle	1			
Beach tennis	1			
Sprint	6	6	1.6	G6 Power sports
High jump	1	19	5.1	G7 Gravity sports
Long jump	1			
Trampolining	17			

The study was carried out according to the principles of the Helsinki Declaration and was approved by the Ethics Committee of the Faculty of Sports of the University of Porto (CEFADE 17.2014). Written informed consent was obtained from all participants.

Statistical analysis

Statistical analyses were done by using the Statistical Package for the Social Sciences (SPSS), version 23 (IBM Corp., Chicago, USA). Quantitative variables were described as medians and interquartile ranges (IQR), and categorical variables as counts and percentages (%). The medians between athletes and the control group were compared by using the Mann-Whitney test, and the proportions by applying the $\chi 2$ test or Fisher´s exact test. The associations were assessed by binary logistic regression analysis with the use of crude and adjusted odds ratios (OR and adj OR) and respective 95% confidence intervals (95%CI). The associations were adjusted for constipation, family history of UI and history of urinary infection, the model was based on the significance of crude associations. Significance level was set at $p < 0.05$.

RESULTS

A total of 744 women were included in this study: 372 in the elite athletes group (AG) and 372 in the control group (CG). The vast majority of the women had normal BMI and did not report constipation or family history of UI. Few were parous or had undergone gynaecologic surgery. The controls presented higher values regarding history of urinary infection. The athletes reported less constipation, had lower parity, and were less likely to have a family history of UI and a history of urinary infection compared with the controls (Table 2).

Fifty (13.4%) athletes and 47 (12.6%) controls (p=0.828) were on medication, most often with nonsteroidal anti-inflammatory agents, antihistamines, and antiasthma drugs.

Table 2. Sociodemographic, anthropometric, medical history, and sports practice characteristics of athletes and controls

	Athletes n=372		Controls n=372		P
	Median	IQR	Median	IQR	
Age, y	19.0	6.0	19.0	6.0	0.858
Sports practice duration, y	9.0	7.0	-	-	
Sports practice frequency, h/week	10.0	8.0	0	0,0	<0.001
	n	%	n	%	
Body mass index (kg/m^2)					
Underweight (<18 Kg/m^2)	3	0.8	27	7.3	<0.001#
Normal (18-25 Kg/m^2)	330	89.7	317	85.2	
Overweight or obesity (25-29.9 Kg/m^2)	35	9.5	28	7.5	
Constipation					
Yes	33	8.9	62	16.7	0.001#
No	339	91.1	310	83.3	
Parous					
Yes	9	2.4	20	5.4	0.037#
No	363	97.6	352	94.6	
Family UI					
Yes	79	21.2	129	34.7	<0.001#
No	293	78.8	243	65.3	
Gynecologic surgery					
Yes	5	1.3	3	0.8	0.725*
No	367	98.7	369	99.2	
History of urinary infection					
Yes	107	28.8	186	50.0	<0.001#
No	265	71.2	186	50.0	

* Fisher's exact test; IQR, interquartile range; # Statistically significant; AG, athlete group; UI, urinary incontinence; SUI, stress UI; UUI, urgency UI; MUI, mixed UI; ICIQ, International Consultation Incontinence Questionnaire.

Prevalence of UI was higher in the AG and SUI was the more prevalent type. Regarding frequency, of those with UI, athletes were less likely to have UI once a week and more likely to have episodes two or three times a week. In both groups, the vast majority of the women reported that the urine loss was of a small amount (Table 3). There was no significant difference between athletes and controls (p=0.292) regarding the overall impact of UI on quality of life (median (IQR); AG: 0.00 (2); CG: 1.00 (2)). Among those who reported UI, 3

(2.7%) athletes and 9 (18%) controls (p=0.002) had previously reported the condition to a physician.

Table 3. Prevalence of urinary incontinence and characteristics of leakage in athletes and controls

	Athletes		Controls		p
	n	%	n	%	
Overall UI	110	29.6	50	13.4	<0.001
SUI	73	19.6	13	3.5	<0.001
UUI	14	3.8	20	5.4	0.292
MUI	22	5.9	3	0.8	<0.001
Others UI	1	0.3	14	3.8	0.001
ICIQ frequency					
About once a week or less often	69	62.7	41	82.0	0.032*#
Two or three times a week	31	28.2	5	10.0	
About once a day	3	2.7	3	6.0	
Several times a day	4	3.6	1	2.0	
All the time	3	2.7	0	0.0	
ICIQ quantity					
A small amount	99	90.0	47	94.0	0.569*
A moderate amount	7	6.4	3	6.0	
A large amount	4	3.6	0	0.0	

*Fisher's exact test; # Statistically significant; UI, urinary incontinence; SUI, stress UI; UUI, urgency UI, MUI, mixed UI; ICIQ, International Consultation Incontinence Questionnaire.

Athletes who practiced gravity sports (G7) reported the highest prevalence of UI (84.4%) compared with all the others sports practice groups (G1: 14.3%, G2: 28.6%, G3: 21.4%, G4: 44.0%, G5: 25.8%, and G6: 33.3%). The differences were statistically significant if all groups were considered (p<0.001), but no differences were found between the other groups after exclusion of G7 (p=0.263).

The prevalence rates of SUI in the different sports disciplines ranged from 0% (figure roller skating, swimming, and weightlifting) to 82.4% (trampolining) (Fig 1).

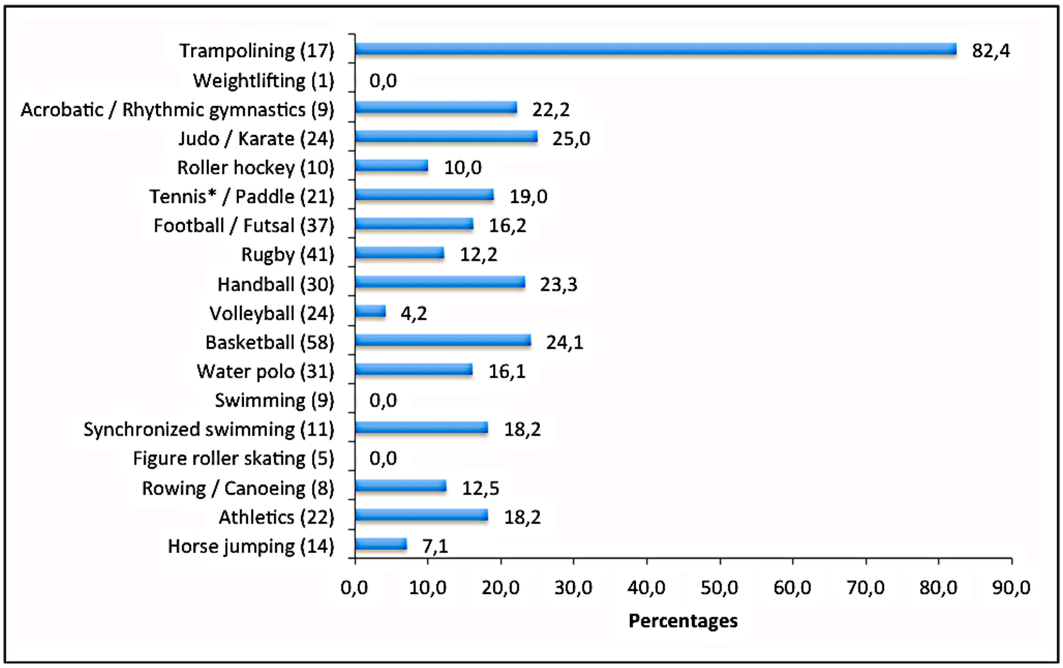

Figure 1. Prevalence (%) of stress urinary incontinence within each sport. *Tennis/Beach tennis/Table tennis

Athletes had three times higher odds of UI than controls and this remained significant after adjusted for constipation, family history of UI, and history of urinary infection. Also, constipation, family history of UI and history of urinary infection had a significant effect (Table 4). In athletes, a weak association was found between UI and hours of practice per week (crude OR=1.04; 95%CI 1.00-1.08). No association was found between UI and years of sports practice (crude OR=1.02; 95%CI 0.98-1.07).

Table 4. Potential risk factors of UI in athletes and controls: multivariate analysis

	Overall UI crude OR (95% CI)	Overall UI adj* OR (95% CI)
Group		
AG	2.70 (1.86-3.92)	3.31 (2.20-4.97)
Control	1.0	1.0
Constipation		
Yes		1.79 (1.07-2.98)
No		1.0
Family history of UI		
Yes		1.54 (1.04-2.29)
No		1.0
History of urinary infection		
Yes		1.53 (1.05-2.23)
No		1.0

*adjusted to all the variables presented in the table; OR, odds ratios; adj OR, adjusted odds ratio; CI, confidence interval.

Most of the athletes with UI (n=110) reported urinary leakage during sports practice (82; 74.5%), often in the middle/at the end of training/competition (69; 84.1%). In 45 (55.6%) athletes, UI occurred only during sports practice. Twelve (14.6%) of the athletes with UI applied strategies to reduce visible leakage, most often the use of pads (9; 75%); 32 (39.1%) considered that the leakage affected their sports performance. None of the athletes with UI representing synchronized swimming, horse jumping, roller hockey, football/futsal, judo/karate or volleyball, reported that UI affected their sports performance.

DISCUSSION

Our study shows a higher prevalence of UI in elite athletes than in controls, with SUI being the most prevalent type of UI. High-level sports practice was associated with three times the odds for UI compared with controls. Additionally, constipation, family history of UI and history of urinary infections were associated with UI. These results correspond with the findings of others studies.[1,5,7,25-27] Because the controls presented higher prevalence rates of these risk factors, one would expect them to have a higher prevalence of UI compared with the elite athletes; however, this was not the case.

Differences between groups regarding BMI, constipation, parity, family history of UI and history of urinary tract infections were found, but these differences were small and may be considered of no clinical relevance. However, as BMI, constipation and to a certain degree, urinary tract infections are modifiable risk factors for UI, prophylactic measures can be implement in order to promote continence. Other studies carried out in young female athletes, either in recreational or competitive sports practice,[28] are in agreement with results reporting high prevalence rates of both UI and SUI.[29] Only a few studies included a control group,[17,19,30,31] and in all except one,[19] a higher prevalence was found in athletes compared with controls. The different prevalence rates obtained may be due to environmental, sociocultural, and genetic factors; the inclusion of a control group is important to rule out the influence of sports practice on the pelvic floor and UI symptoms.

How the prevalence of UI compares in different sports

In the present study, differences in the prevalence of UI were also found across sports groups, with the rates ranging from 14.3% in technical sports to 84.4% in gravity sports. Contradictory to our findings, in other studies, the highest rates were obtained in technical sports,[19,31] and the lowest in gravity sports.[31] Differences in the sports included in these studies may explain this finding. Consistently with former research,[17,18,21,32] female trampoliners showed the highest prevalence of SUI. One would think that the impact leading to leakage would be the landing phase. However, Eliasson et al.[32] found that leakage occurred mainly when doing double somersaults and when rehearsing new, strenuous, and difficult exercises.

Regarding horse riding, to our knowledge, this is the first study to report on the prevalence of UI in horse riding female elite athletes competing in horse jumping events; the rate is among the lowest values obtained for the different sports modalities in this study.[33] Alanee et al.[33] found that female horse riders did not present an increased risk of UI and suggested that equestrian sports might rather decrease the risk of female UI. Riders contract the hip adductors to maintain their balance, and a synergistic contraction of the striated urethral wall muscle and the PFM has been found during hip adductor muscle contraction[34]; thus, horse riding might strengthen the PFM. To our knowledge, no previous studies have evaluated the muscle strength of the PFM in horseback riders. Further clinical studies are needed to clarify this hypothesis.

Regarding ball games, the volleyball athletes in our study reported a significantly lower prevalence of SUI compared with, for example, basketball and roller hockey. There are inconsistences across studies in the reported prevalence rates of UI in volleyball, which vary between 4.3% and 44.4%.[17,35,36] Although volleyball players perform leaps in the execution of a shot, they have a more stationary stance because they do not move across the field throughout the game. Thus, the impact of ground reaction forces on the pelvic floor may be less in volleyball than in other high impact sports. However, one study found that female volleyball players had significantly weaker PFM strength compared with a non-exercising control group and that low PFM strength was correlated with SUI.[37]

Another interesting difference found in the present study was between athletes in aquatic sports disciplines, in which none of the swimmers reported SUI, in contrast with those in water polo and synchronized swimming athletes. Other studies have a wide prevalence range in swimmers, varying from 6%[16] to 84.6%.[17] Although in aquatic sports the body is partially immersed in water, and therefore ground reaction forces have no impact on the pelvic floor, some differences could exist between modalities in terms of abrupt and repetitive increases in IAP due to twisting and other specific sport body movements. However, the prevalence of UI may also be underestimated in water, as the leakage may be more difficult to perceive; that is, the leakage is hard to see, and there is no smell of urine.

The finding that more than half of the athletes reported UI only during sports practice, more frequently in the middle/at the end of training/competition sessions, and that training volume was found to be associated with UI, indicates that both PFM strength and endurance may be required to stay dry. A decrease in the maximum voluntary contraction of the PFM after strenuous exercise has been observed in young nulliparous women with SUI.[38] Thus, there is a need to develop valid methods of measuring the PFM function during different sports activities.

Effect on sports performance

More than one third of the athletes considered UI to have implications on sports performance; however, less than 15% reported using strategies to hide the leakage, and significantly fewer athletes than controls had told a physician about the condition. Not telling health care professionals about UI is common.[16,20,39] Because this behaviour seems to have persisted in the last two decades, there is a need to implement educational programs for health care providers, fitness instructors, and coaches.[15] Some studies indicates that presence of UI at a young age[40,41] and strenuous activity during teen years[42] may be a risk factor for later UI. Hence, interventions to prevent and treat the condition at an early stage is important.[5] There is strong evidence that PFM training is an effective treatment for SUI in the general female population, and there is international consensus that PFMT should be a first-line treatment for SUI and MUI.[43] To date, no randomized controlled trials of PFMT to prevent or treat SUI in female elite athletes have been carried out, and there is little knowledge about strenuous exercise as a risk factor for the development of UI.[15] Three small case studies on PFM training in female athletes showed promising results.[44-46] However, this observed effect has to be evaluated in RCTs of high methodological quality.

As our AG comprised athletes that were on the respective national teams for at least one year, some athletes might have quit competition due to UI. Consequently, prevalence rate of UI may be under-reported.

Strengths and limitations

The strengths of the present study are the large sample size, which included sports that had not been previously investigated; the high response rate; the comparison with an age-matched control group; and the use of a reliable and validated questionnaire to assess UI.[22] The limitations of this research are the use of questionnaires only, with no additional urodynamic or other clinical assessment methods to verify UI. In addition, the sample sizes for some of the sports groups were small. Although some sports were merged into larger groups,[19] the sample sizes may still have been too small to register statistically significant differences between some groups.

CONCLUSION

The present study found a higher prevalence of UI among Portuguese elite athletes compared with age-matched controls, and high-level sports practice was identified as an independent risk factor for UI. Besides high-level sports practice, constipation, familiar history of UI, and history of urinary infections were also associated with high odds of UI.

What is known about the topic
The prevalence of urinary incontinence among elite athletes is high and the reported prevalence rates vary widely between sport disciplines. High impact sports are associated with the highest prevalence of urinary incontinence.

What this study adds
This study compared the prevalence of urinary incontinence between a young population of elite athletes and an age-matched control group. The prevalence rates of urinary incontinence in sports modalities that had not been previously reported were presented, e.g., roller hockey, figure roller-skating, and water polo. Some modifiable risk factors were identified, which could help in the development of prevention and treatment strategies for this specific group.

Contributors AC was involved in planning the study, reviewed and analysed the literature, wrote the paper, draft and approved the final version. RNJ critically revised the article and approved the final version. KB was involved in planning the study, critically revised the article and approved the final version.

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Competing interest None

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Study II

Urinary incontinence and disordered eating in female elite athletes

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Abstract

Objectives To evaluate the association between urinary incontinence and disordered eating, in elite female athletes.

Design This is the secondary analysis of a cross-sectional study included 744 young and healthy Portuguese women: 372 elite athletes and 372 age-matched non-athletes, median age 19 (range15 - 48) years.

Methods Data regarding clinical, demographic, and sport practice characteristics were collected by questionnaire. The International Consultation on Urinary Incontinence Questionnaire-Urinary Incontinence-Short Form was applied to identify urinary incontinence. The Eating Disorder Examination Questionnaire was applied to identify disordered eating. Odds ratios with 95% confidence intervals (95% CI) were used to estimate the association between UI and disordered eating.

Results The prevalence of urinary incontinence in athletes and non-athletes was 29.3% and 13.4%, $p<0.001$, respectively. No difference in prevalence of disordered eating was found between athletes (17.7%) and non-athletes (20.2%), $p=0.435$. Urinary incontinence was associated with disordered eating only in the athletes. After adjustment for age, type of sport, smoking and alcohol intake, athletes with disordered eating presented increased odds of urinary incontinence of any type than athletes without disordered eating (OR=3.12; 95% CI: 1.74-5.59).

Conclusions Athletes with disordered eating were three times more likely to present urinary incontinence than women without disordered eating. There is a need for further studies to elaborate on mechanisms for this association.

Keywords: EATING BEHAVIOUR; SPORTS PRACTICE; PELVIC FLOOR DYSFUNCTION; PREVALENCE; STRESS URINARY INCONTINENCE

1. Introduction

Urinary incontinence (UI) is defined as "the complaint of any involuntary leakage of urine"[1] and has shown to be common among athletes[2] especially in sports involving high-impact activities.[3,4] Some research groups report a higher prevalence of UI in athletes compared to non-athletes.[2,4] However, some research groups also report contradictory results.[5]

The Academy of Nutrition and Dietetics, Dietitians of Canada/The American College of Sports Medicine[6] stated that, "the performance of, and recovery from, sporting activities are enhanced by well-chosen nutrition strategies". Female athletes, in order to optimize body size and composition for competitive success, may have abnormal disordered eating attitudes and behaviors such as, restrictive eating, fasting, frequent skipping meals, use of diet pills, laxatives, diuretics, enemas, overeating, binge-eating and purging.[7,8] This may result in lack of some important key macro and micro-nutrients important for proper skeletal muscle function.[6] Consequently it can be hypothesized that disordered eating also may weaken skeletal muscles, including the pelvic floor muscles.
The prevalence of disordered eating have been shown to be higher in female athletes compared to non-athletes.[9] Furthermore, athletes competing at an elite level present higher rates of disordered eating than those who are not engaged in competition or compete at a recreational level.[8]
Despite an increased risk of both UI[2] and disordered eating[9] in female athletes, few studies have addressed the association between UI and disordered eating.
The aim of the present study was to assess the association between urinary incontinence and disordered eating among Portuguese female elite athletes and non-athletes. This is a secondary analysis of a previously published study evaluating the prevalence of UI and potential risk factors.[2]

2. Methods

This is a cross-sectional study of Portuguese elite female athletes. Details of the study population were fully reported in a former study on the prevalence of UI among elite female athletes and controls.[2]

Subjects

The sample included 372 elite female athletes (AG) aged 15-48 years actively competing in their respective national teams for at least one year and who had reached an international competition level. A control group of 372 non-athlete females (NAG), exercising twice weekly or less were recruited in high schools, universities and public areas, matched by age (±1 year) in a 1:1 ratio. Exclusion criteria were pregnancy at the time of the study or during the past year, any illnesses and inability to understand the Portuguese language.

Data collection

Data regarding general background variables, such as age, weight, height, parity, smoking habits (yes/no) and intake of alcohol beverages (<1/week/≥1/week) on a regular basis; general medical and gynecological history, menstrual status in the last 4 months and the use of hormonal contraceptives; exercise practice characteristics such as type of sport, years of sport participation, and volume of training (hours/week), were collected through self-administered questionnaires.

UI was assessed by the International Consultation on Incontinence Questionnaire-Urinary Incontinence-Short Form (ICIQ-UI-SF)[10] which is a reliable and valid questionnaire for assessing prevalence, severity, overall impact on quality of UI, and type of UI.[10] The ICIQ-UI-SF has been translated into the Portuguese language and validated.[11] The questionnaire includes three scored items. The first item assesses frequency of leakage (0, never to 5, all the time), the second item assesses amount of leakage (0, none to 6, a large amount) and, the third item determines the overall impact of UI on health related quality of life (a numeric scale is used, ranging from 0, not at all, to 10, a great deal). A fourth non-scored item asks about the patient's perception of the type of leakage. For the purpose of the present study, UI was operationalized to participants reporting involuntary urine loss of any type (one or more positive responses to the fourth item of the ICIQ-UI-SF). Positive responses to involuntary loss of urine associated with coughing, sneezing, physical activity or exercise was classified as stress urinary incontinence (SUI). Involuntary loss of urine before reaching the toilet was classified as urgency urinary incontinence (UUI).

Disordered eating was evaluated through the Eating Disorder Examination Questionnaire (EDE-Q),[12] which assesses the core features of eating disorder psychopathology. The EDE-Q has been translated and validated for the Portuguese language.[13] The 22 items are scored using a 7-point (i.e. 0–6), forced-choice rating scheme focusing on the past 28 days. It comprises four subscales: Restraint, Eating Concern, Shape Concern, and Weight Concern. The average of the four subscales generates a global score, with higher scores indicating greater psychopathology. Cut-off values for the global score and for the specific subscales have been previously reported for young Portuguese women (global score: 2.12; Restraint: 1.49; Eating Concern: 1.37; Weight Concern: 2.63; and Shape Concern: 2.12).[13] Participants were classified as having disordered eating if they had a score above the global cut-off score. Pathogenic weight-control behaviors were assessed by 3 items of the EDE-Q: use of laxatives, self-induced vomiting and exercise specifically to control their weight.

In women who did not use hormonal contraceptives methods, the criteria for classifying participants with menstrual dysfunction were: absence of onset of menarche (primary amenorrhea); 3 or 4 missed periods reported after menarche (secondary amenorrhea); menstrual cycles of 35 days or more (oligomenorrhea).[14]

The sports included in the present study were classified as leanness or non-leanness sports (Table 1) as previously described by Torstveit and Sundgot Borgen.[15] Leanness sports comprised sports in which leanness and/or body weight were considered important for performance e.g. gymnastics, swimming, middle-distance running. Non-leanness sports comprised sport where leanness was considered less important for performance e.g. ball games and sprint.[15]

Table 1. Sports disciplines in leanness and non-leanness sports groups and the corresponding number of participants

Leanness sports 100 (26.9%)	n	Non-Leanness sports 272 (73.1%)	n
Swimming	9	Soccer	35
Middle-distance running	14	Indoor soccer	2
Rowing	3	Basketball	58
Canoeing	5	Roller hockey	10
Figure roller skating	5	Handball	30
Synchronized swimming	11	Volleyball	24
Acrobatic gymnastics	3	Water polo	31
Rhythmic gymnastics	6	Rugby	41
Karate	3	Tennis	14
Judo	21	Table tennis	5
Weight lifting	1	Paddle	1
High jump	1	Beach tennis	1
Long jump	1	Sprint	6
Trampolining	17	Horse jumping	14

Ethics

The study was carried out according to the principles of the Helsinki Declaration and was approved by the Ethics Committee of the Faculty of Sports of the University of Porto (CEFADE 17.2014). Written informed consent was obtained from all participants.

Data analysis

Categorical data are presented as counts and proportions and continuous data as median and interquartile range (IQR). Chi-square test was used to test the independency between categorical variables, and the Mann-Whitney test to compare medians between groups.

The magnitude of the association between urinary incontinence and disordered eating (global score of the EDE-Q) was estimated using odds ratio (OR) with 95% confidence intervals (CI) through binary logistic regression models.

Estimates were adjusted for age, type of sports (leanness vs. non-leanness), smoking and alcohol intake.

Statistical analyses were conducted using SPSS (IBM Corp. Released 2014. IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.), and the significance level was set at 0.05 for two-sided tests.

3. Results

The sample included young women with no reported comorbidities. Athletes presented a higher prevalence of any UI and SUI than non-athletes. A full description of the prevalence rates of the different UI types has been published elsewhere.[2] All participants had reached menarche and therefore no cases of primary amenorrhea were reported.

Few athletes and non-athletes reported menstrual dysfunction (Table 2). Concerning pathogenic weight control methods, more athletes than non-athletes reported intensification of exercising to control their weight. Athletes reported less frequently being smokers or drinking alcoholic beverages, in comparison to non-athletes. More non-athletes than athletes were parous. Regarding disordered eating, no differences between athletes and non-athletes were found in the global score of the EDE-Q (>2.12 in the global score was found in 17.7% of athletes and 20.2% of non-athletes). Regarding the subscales, there were differences only in the prevalence of restraint between athletes and non-athletes. Fewer athletes than non-athletes used hormonal contraceptive methods (34.4% and 57.8%; $p<0.001$, respectively). No association between menstrual dysfunction and UI was found in any of the groups ($p>0.05$).

Table 2. Participants' characteristics, prevalence of urinary incontinence and disordered eating behaviours among athletes and non-athletes

	Athletes n=372	Non-athletes n=372	
	Median (IQR)	Median (IQR)	p-value
Age (years)	19.0 (7.0)	19.0 (6.0)	0.859
Sports practice duration (years)	9.0 (7.0)	-	
Sports practice frequency (hours/week)	10.0 (8.0)	0 (0)	<0.001
	n (%)	n (%)	p-value
Urinary incontinence			
Any	109 (29.3)	50 (13.4)	<0.001
SUI	95 (25.5)	16 (4.3)	<0.001
UUI	35 (9.4)	23 (6.2)	0.133
Menstrual dysfunction			
Yes	26 (7.0)	21 (5.6)	0.547
Parous			
Yes	9 (2.4)	20 (5.4)	0.037
PWCM			
Vomiting	6 (1.6)	8 (2.2)	0.611
Laxatives	8 (2.2)	9 (2.4)	0.828
Increased Exercise	70 (19.1)	34 (9.1)	<0.001
Smoking			
Yes	17 (4.6)	91 (24.5)	<0.001
Alcoholic beverages			
<1/week	329 (88.7)	107 (28.8)	
≥1/week	42 (11.3)	264 (71.2)	<0.001
EDE-Q global score			
≤2.12	298 (82.3)	296 (79.8)	
>2.12	64 (17.7)	75 (20.2)	0.435
EDE-Q subscales			
Restraint			
≤1.49	230 (61.8)	280 (75.3)	
>1.49	142 (38.2)	92 (24.7)	<0.001
Eating concern			
≤1.37	311 (85.4)	323 (87.1)	
>1.37	53 (14.6)	48 (12.9)	0.595
Shape concern			
≤2.12	275 (74.7)	266 (71.5)	
>2.12	93 (25.3)	106 (28.5)	0.365
Weight concern			
≤2.63	287 (78.0)	277 (74.5)	
>2.63	81 (22.0)	95 (25.5)	0.298

EDE-Q, Eating Disorder Examination Questionnaire; IQR, interquartile range; SUI, stress urinary incontinence; UUI, urgency urinary incontinence; PWCM, pathogenic weight control methods.

There was no statistical significant difference in prevalence of disordered eating between those practicing leanness sports compared with non-leanness sports, except for the restraint sub-scale (Table 3).

Table 3. Prevalence of disordered eating assessed through the EDE-Q, in athletes, according to type of sport

	Leanness sports	Non- leanness sports	
	n (%)	n (%)	p-value
EDE-Q global score			
≤2.12	51 (73.9)	227 (83.8)	
>2.12	18 (26.1)	44 (16.2)	0.086
EDE-Q subscales			
Restraint			
≤1.49	35 (47.9)	185 (66.8)	
>1.49	38 (52.1)	92 (33.2)	0.005
Eating concern			
≤1.37	58 (82.9)	235 (86.4)	
>1.37	12 (17.1)	37 (13.6)	0.574
Shape concern			
≤2.12	48 (67.6)	208 (75.6)	
>2.12	23 (32.4)	67 (24.4)	0.221
Weight concern			
≤2.63	51 (72.9)	218 (70.0)	
>2.63	19 (27.1)	58 (21.0)	0.347

EDE-Q, Eating Disorder Examination Questionnaire.

There was no association between UI and disordered eating (any UI, SUI and UUI) in non-athletes. In athletes, the prevalence of UI of any type was higher among those with disordered eating, classified according to the global score of EDE-Q. Differences were also found in the prevalence of SUI and UUI according to the global score of the EDE-Q. When considering the EDE-Q subscales, prevalence of any UI and SUI was higher among those with higher scores in each of the subscales, but no statistically significant differences were found for UUI, although there was a similar trend (Table 4).

Table 4. Prevalence of urinary incontinence according to disordered eating, in athletes and non-athletes. Numbers with (%)

	Athletes			Non-athletes		
	Any UI	SUI	UUI	Any UI	SUI	UUI
EDE-Q global score						
≤2.12	75 (25.2)	63 (21.1)	23 (7.7)	40 (13.5)	11 (3.7)	18 (6.1)
>2.12	32 (50.0)	30 (46.9)	12 (18.8)	10 (13.3)	5 (6.7)	5 (6.7)
	p<0.001	*p<0.001*	*p=0.013*	*p=0.967*	*p=0.335*	*p=0.792*
EDE-Q subscales						
Restraint						
≤1.49	57 (24.8)	48 (20.9)	19 (8.3)	40 (14.3)	11 (3.9)	20 (7.1)
>1.49	52 (36.6)	47 (33.1)	16 (11.3)	10 (10.9)	5 (5.4)	3 (3.3)
	p=0.020	*p=0.012*	*p=0.434*	*p=0.511*	*p=0.557*	*p=0.275*
Eating concern						
≤1.37	84 (27.0)	73 (23.5)	27 (8.7)	42 (13.0)	12 (3.7)	19 (5.9)
>1.37	24 (45.3)	21 (39.6)	8 (15.1)	8 (16.7)	4 (8.3)	4 (8.3)
	p=0.011	*p=0.021*	*p=0.226*	*p=0.640*	*p=0.139*	*p=0.519*
Shape concern						
≤2.12	70 (25.5)	58 (21.1)	21 (7.6)	38 (14.3)	10 (3.8)	17 (6.4)
>2.12	39 (41.9)	37 (39.8)	14 (15.1)	12 (11.3)	6 (5.7)	6 (5.7)
	p=0.004	*p=0.001*	*p=0.057*	*p=0.556*	*p=0.406*	*p=0.980*
Weight concern						
≤2.63	77 (26.8)	65 (22.6)	23 (8.0)	39 (14.1)	10 (3.6)	18 (6.5)
>2.63	31 (38.3)	29 (35.8)	12 (14.8)	11 (11.6)	6 (6.3)	5 (5.3)
	p=0.063	*p=0.024*	*p=0.104*	*p=0.658*	*p=0.254*	*p=0.854*

EDE-Q, Eating Disorder Examination Questionnaire; UI, urinary incontinence; SUI, stress urinary incontinence; UUI, urgency urinary incontinence.

When combining athletes and controls, the interaction between the groups and ED on UI was p=0.020. Since no association between UI and disordered eating was found in non-athletes, the magnitude of the association was only estimated in athletes. The vast majority of athletes (2.4%) were nulliparous and therefore, parity was not considered a confounding variable. After adjustment for age, type of sports, smoking and alcohol intake, athletes scoring higher than 2.12 in the global EDE-Q score, were about 3 times more likely to present UI of any type (OR=3.12; 95% CI 1.74-5.59) in comparison to those without disordered eating. Athletes with disordered eating also presented increased odds of SUI and UUI, 3.3 and 2.3, respectively (Table 5).

Table 5. Association between disordered eating and urinary incontinence (any urinary incontinence, stress urinary incontinence and urgency urinary incontinence) in athletes

	Any UI	SUI	UUI
	Crude OR (95% CI)		
EDE-Q global score			
≤2.12	Ref.	Ref.	Ref.
>2.12	2.97 (1.71-5.18)	3.29 (1.87-5.79)	2.76 (1.29-5.89)
	Adjusted* OR (95% CI)		
EDE-Q global score			
≤2.12	Ref.	Ref.	Ref.
>2.12	3.12 (1.74-5.59)	3.27 (1.81-5.92)	2.68 (1.20-5.99)

*Adjusted for age, type of sports (leanness vs. non-leanness), smoking, alcohol intake. EDE-Q, Eating Disorder Examination Questionnaire; UI, urinary incontinence; SUI, stress urinary incontinence; UUI, urgency urinary incontinence; OR, odds ratios.

Analyses were repeated using continuous scores of the EDE-Q and the associations observed between UI and disordered eating retrieved similar results (data not shown).

4. Discussion

This study aimed to examine the association between UI and disordered eating in elite athletes. Elite female athletes with disordered eating were 3 times more likely to present UI than athletes without disordered eating. The prevalence of any UI and SUI was higher in athletes. No difference was found in the prevalence of disordered eating neither between athletes nor non-athletes, nor between athletes participating in leanness and non-leanness sports.

In the present study, UI was associated with disordered eating only in the athlete group. Two studies, one in a small sample of female runners[17] and another in a large sample of elite female athletes,[5] found a higher prevalence of UI in disordered eating than in non disordered eating athletes. However, these studies did not report the magnitude of the association between UI and disordered eating and did not control for confounding factors. In the present study, athletes with disordered eating presented 3 times higher odds of UI after adjusting for potential confounders, suggesting that disordered eating could play a role in UI in female athletes.

Although reporting different prevalence estimates of disordered eating, other studies have reported the same trend of disordered eating prevalence between female athletes from different sports and controls.[9,17] Concerning type of sports (leanness vs non-leanness) our results were not in line with previous findings. A recent review,[18] revealed that disordered eating is more prevalent among elite female athletes practicing sports that emphasize leanness or low body weight such as, endurance and aesthetic sports and, the prevalence rates in those athletes can be as high as 48.9%.[17] The wide range of prevalence of disordered eating described in the literature can be due to different sample sizes,[9] type of sports included,[8] use of different definitions,[18] investigations at different seasons, investigators (coach, researchers), age groups[19] and psychological factors.[8] All the athletes included in the present study competed at the highest level and were closely monitored by a multidisciplinary team. Besides information and advice about proper nutrition, the clinical teams of all the Portuguese Sports Federations have a careful dietary plan both during the training and competition periods. This might be one explanation for our results.

Regarding the EDE-Q subscales, more athletes than non-athletes and more athletes from leanness than non-leanness sports reported a restrictive eating behavior. A lack of proper nutrition has been demonstrated in high-level female athletes,[20,21] compromising the intake of essential macro (carbohydrates, proteins) and micro-nutrients (vitamins B and D)[21] needed to support a proper skeletal muscle function.[6] A suboptimal intake of carbohydrate, could result in premature muscle glycogen depletion during training and competition leading to muscle fatigue.[22] Also, the lack of some key micronutrients, such as iron, vitamin D and calcium have been referred to play an important role on skeletal muscle function.[6] Striated muscles of the pelvic floor, including the urethral sphincter muscle, contribute to the urethral support system and increase in maximal urethral closure pressure during increases in intra-abdominal pressure.[23] However, in the present study we have no data on PFM function and no data on nutrition. The underlying mechanism is therefore still unknown, and needs further investigation.

Participation of young girls in sports at a high competition level is increasing. Due to the intensity of training there may be an increased risk of musculoskeletal injuries.[24] However, there are no studies on the PFM structures in teen elite female athletes. Nygaard et al[25] found in a sample of middle-aged women, that greater strenuous activity during teen years increased the odds of SUI later in life (OR, 1.37 per 7 additional h/wk; 95% CI, 1.09-1.71; P=0.006). Also, UI during sport practice can lead to decreased sport performance.[26,27,28] Further studies are needed to identify risk factors for UI related to sport practice.

Disordered eating and menstrual dysfunction may be interrelated conditions in female athletes.[7] Menstrual dysfunction such as delayed menarche and disruption of normal menstrual cycles has been recognized to be frequent in female athletes performing high intensity training.[20,21] In the present study, and as observed for disordered eating, no difference in menstrual dysfunction prevalence between athletes and non-athletes was found. However, a higher prevalence of menstrual dysfunction among athletes than non-athletes have been reported in another study[29] while results of one study corresponds with our results.[15] The finding that a large number of the participants of the present study used hormonal contraceptives could mask menstrual dysfunction and should be considered when interpreting the results.

The strengths of the present study are the large sample size, with inclusion of athletes competing at an international level and from a wide variety of sports, the high response rate and the comparison with an age-matched control group. However, some limitations should be acknowledged: disordered eating and menstrual status were assessed by self-reporting and clinical evaluation was not performed. The prevalence of disordered eating may be underreported due to self-report. Torstveit et al.,[17] emphasized the importance of a clinical interview in order to identify disordered eating, especially for leanness sport athletes, since, over 14% of athletes were classified as false-negatives in their study. Additionally, EDE-Q was not developed for use in athlete populations. However, it has been used to assess disordered eating in athletes and the cutoff points considered in the present study were estimated for young Portuguese women. The lower number of participants in the leanness groups may have influenced the results. The fact that we had no data on PFM function (assessment of PFM resting condition, strength and endurance) is also a limitation.

5. Conclusion

Athletes with disordered eating were 3 times more likely to report urinary incontinence than women without disordered eating. Stress urinary incontinence was the most prevalent type of urinary incontinence among athletes and the prevalence was higher in athletes than non-athletes. No differences were found in prevalence of disordered eating between elite female athletes and non-athletes. In athletes, prevalence of disordered eating was higher in those practicing leanness sports. We therefore recommend that elite female athletes should be screened for both UI and disordered eating. Prevention and treatment strategies in female athletes for both conditions should be evaluated in future high quality RCTs.

Practical Implications

- Elite athletes presented high prevalence of stress urinary incontinence. Athletes may abandon their favourite sport or limit their practice due to urine leakage. Identifying potential related risk factors for urinary incontinence is crucial to developing preventive measures for this condition.
- Both urinary incontinence and disordered eating can have a negative impact on the athletes' wellbeing. The data in the current study suggests that athletes with altered eating behaviours have higher odds of

presenting urinary incontinence than women without disordered eating.

- Restrictive eating behaviours may compromise the intake of important nutrients that support high performance sports activity. Athletes should be screened for disordered eating and educational programs should be implemented in this population in order to avoid unhealthy eating behaviours.

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Study III

Association between physical activity level and pelvic floor muscle variables in women

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ABSTRACT
In order to investigate the potential impact of physical activity (PA) on pelvic floor muscle (PFM) function, a cross-sectional study was made to analyse the association between PA level and vaginal resting pressure (VRP) and PFM strength and endurance. Thirty-eight continent women and 20 women with stress urinary incontinence (SUI) aged 19 to 49 years were enrolled in the study. PFM variables were assessed by manometry. The PA level was assessed through the International Physical Activity Questionnaire - Short Form. The International Consultation on Urinary Incontinence Questionnaire-Urinary Incontinence - Short Form was applied to identify SUI. Pearson's correlation coefficients were applied to estimate the association between PA and PFM variables. Incontinent women were classified as having a high PA level compared to the continent ones (65.0% vs 34.2%, respectively; p=0.030). There was a positive weak association between PA and VRP in continent (r=0.377) and an inverse association in incontinent women (r=-0.458). No associations were found between PA and PFM strength and endurance. Further studies are needed in order to identify a causal association between PA and SUI.

Introduction

Urinary incontinence (UI) is a common pelvic floor dysfunction in women of all ages, with stress urinary incontinence (SUI) being the most common type [29]. SUI is defined by the International Urogynecological Association (IUGA)/International Continence Society (ICS) [27] as "a complaint of involuntary loss of urine on effort or physical exertion (e.g. such as sporting activities), or on sneezing or coughing".

Physical activity (PA) includes not only recreational and regular exercise training, but also PA during household tasks and other work-related and transport-related PA [14]. Concerning the relationship between PA and UI, a

recent review [34] indicated that current leisure time activity and mild to moderate PA both decreased the risk of having UI, whereas a lack of PA or strenuous exercise/heavy workload may increase the risk.
In relation to the effect of PA on the pelvic floor, two opposing hypotheses have been proposed [6]. The first hypothesis postulates that female athletes may have strong pelvic floor muscles (PFM), explained by the fact that any rise in intra-abdominal pressure (IAP), such as occurs during general PA will lead to a simultaneous or pre-contraction of the PFM. Based on this rationale it would be expected that women with higher levels of PA should have higher PFM strength and endurance. The other hypothesis suggests that if there is not adequate co-contraction of the PFM, strenuous PA may overload, stretch and weaken the connective tissue and muscles of the pelvic floor. To date, the high prevalence of UI found in female athletes appears to support the latter hypothesis [2, 13].

Thus far there is sparse knowledge on the impact of the total amount of PA on prevalence of UI in young women [34], or on the association between PA level and PFM vaginal resting pressure (VRP), strength and endurance.

The aim of the present study was to analyse the association between PA level and PFM variables in continent women and women with SUI symptoms.

Materials & Methods

This is a cross-sectional study. Data were collected during May, June and July 2016 and May and June 2017. The study was approved by the Research Ethics Committee of the Faculty of Sports, University of Porto, Portugal (09.2016). Written informed consent was obtained from all the participants. The study meets the ethical standards of the International journal of Sports Medicine [26].

Participants were recruited via personal contact among staff and students from University of Porto, Portugal.

Inclusion criteria were to be over eighteen years-old, sexually active, and if parous, to be more than one year postpartum. Incontinent women had to report symptoms of SUI. Subjects were excluded if they reported back, pelvic or hip pain, had been submitted to gynecological surgery, or if they were diagnosed with any neurological or respiratory diseases, urinary tract or vaginal infection or pelvic organ prolapse, inability to perform a correct PFM contraction or inability to insert or maintain the vaginal probe due to pain or discomfort.

Data collection

Data related to background variables were collected by self-administered questionnaires.

Performing PFMT training was defined as yes to the question: "Do you regularly exercise the PFM?"

ICIQ-UI-SF was applied to assess severity, overall impact of UI and type of UI [4]. The ICIQ-UI-SF has been translated into the Portuguese language and validated by Tamanini et al. [43]. For the purpose of the present study, SUI was assigned to participants with positive responses to involuntary loss of urine associated with coughing, sneezing, PA or exercise. If no involuntary loss of urine was reported the subject was classified as continent.

Physical activity level was evaluated through the International Physical Activity Questionnaire - Short Form (IPAQ-SF) [17]. The questionnaire is comprised of questions regarding three specific types of activity: walking, moderate intensity activities and vigorous intensity activities (undertaken in leisure time, domestic and gardening activities, work-related and transport-related PA). For each type of activity, the total weekly PA in metabolic equivalent task-minute/week (MET–min/wk) was calculated using the formula min. of an activity per day x the numbers of days per week x the specific MET score for each activity. Intensity is estimated as total weekly PA expressed in MET–min/wk, computed by the summation of walking + moderate + vigorous MET–min/wk scores. Levels of PA were categorised as low, moderate or high intensity, according to the IPAQ protocol (www.ipaq.ki.se).

VRP, PFM strength and PFM endurance were assessed by manometry using the Peritron Perineometer 9300 (LABORIE Medical Technologies Canada ULC.), which has been found to be a reliable method of measuring PFM strength [22] and endurance [23, 38]. The vaginal probe was covered with a condom. Before insertion the device was zeroed. The participant inserted the probe herself, until 2 cm remained outside the introitus [37]. An inward and posterior movement of the probe was monitored in all measurements to ensure correct contraction of the PFM [9]. After insertion of the probe, the participants were instructed to relax the PFM and a rest period was given to control the influence of voluntary or involuntary activation of the muscles on the resting tone due to insertion of the probe. The lowest pressure value during rest was used as a measure of VRP. After zeroing, the women were asked to perform a maximal voluntary contraction (MVC) hold it for 3 sec. and the peak value was recorded. This procedure was repeated 3 times and the mean value was used as a measure of PFM strength [23]. A value corresponding to 60% of the mean value of the PFM strength was determined for each woman as a goal for submaximal contraction [1]. Women were instructed to perform a voluntary contraction whilst maintaining a squeeze pressure above 60% of their MVC for as long as possible [37]. Verbal encouragement was given to maintain this contraction until the pressure fell below 60% or signs of co-contractions or compensatory movements occurred. The duration in sec. of this contraction was used as a measure of PFM endurance. To prevent muscle fatigue, a rest period of 30 sec. was given after every contraction and 60 sec. between the different measurements. We used standardized instructions for all participants: for the VRP, the instruction was “Breathe calmly, do not think about your pelvic floor and stay in a relaxed situation”; Instruction for the PFM MVCs was: “Use your PFMs as if you want to stop urination and contract as hard as you can, hold for 3 sec. and then relax and breathe normally”; Instructions for the sustained contraction was: “Hold the contraction of your PFMs as shown as 60% of your maximal PFM contraction for as long as possible”. During PFM assessment we allowed a small visible in-drawing of the abdominal muscles, as long as the pelvis was not tilted [10]. Participants were instructed to not move the trunk and feet and the investigator controlled this by observation. The physiotherapist assessing the PFM variables was blinded to PA level.

Procedures

After filling in the questionnaires, the participants were examined with translabial ultrasonography to assess the ability to perform a correct PFM contraction, and then manometry. The sequence of the manometry measurement was: 1) VRP, 2) PFM strength and, 3) PFM endurance. Measurements were obtained by the same investigator (AC) following standardized methodology. For each participant all tests were performed on the same day in the same order. Since SUI usually occurs in an upright position all measurements were performed while standing [7].

Methods, definitions and units conform to the standards jointly recommended by the International Continence Society and the International Urogynecological Association, except where specifically noted [8, 27].

Data analysis

All statistical analyses were performed using SPSS statistical software package version 24.0 (SPSS inc., Chicago IL., USA).
For continuous variables, normality was checked by visual inspection of the histogram, boxplot and Q-Q plot before the choice of statistical analysis. To compare characteristics of participants by urinary continence status, we used Mann-Whitney for continuous variables and Chi-square tests for categorical variables. Significance level was set at 5%. Variables without normal distribution were log transformed. Associations between PA level and measures of PFM variables were evaluated through Pearson´s correlation coefficients, according to urinary continence status. To control for potential confounding factors a linear

regression analysis was conducted addressing age, BMI, constipation, parity status, type of delivery and PFM training.

RESULTS

A total of 64 women fulfilled the study criteria; four declined to participate. Reasons given for declining were that they did not want to undertake tests that involved vaginal assessment. In addition, 2 participants were excluded due to pain when inserting the probe. Four women were not able to perform a correct PFM contraction at their first attempt, but all of them were able to contract correctly after instruction [10]. The final sample comprised 58 healthy women aged 19 to 49 years, 38 were continent and 20 had SUI symptoms. Four out of 20 SUI women also reported urgency UI symptoms. Forty-one (71%) women were engaged in regular exercise practice, 31(76%) in low impact activities (zumba, cross fit, bodybuilding, pilates) and 10 (24%) in high impact activities (volleyball, futsal, tennis, basketball).

Regarding frequency of leakage, 12 (60.0%) SUI women reported that urine loss occurred once a week or less often, 7 (35.0%) reported two or three times a week and 1 (5%) several times a day. All SUI women reported a small amount of leakage. The median (IQR) overall impact of UI was 1.5 (4.0).

Table 1 shows the background variables of the participants. In both groups, the majority of the women had normal or underweight BMI, were nulliparous and did not report constipation. Approximately one quarter reported performing regular PFM training. There were no statistically significant differences between groups in any background variable (Table 1).

Table 1 – Background characteristics of continent and incontinent women

	Total (n=58)	Continent (n=38)	Incontinent (n=20)	p-value
	median (IQR)	median (IQR)	median (IQR)	
Age	23.0 (10.0)	24.0 (7.0)	21.0 (15.0)	0.147[a]
PFM strength (cmH_2O)	51.2 (26.21)	53.3 (27.23)	46.7 (15.42)	0.513[a]
PFM endurance (s)	35.9 (34.28)	36.8 (29.75)	27.5 (42.88)	0.390[a]
VRP, mean (SD) (cmH_2O)	45.9 (9.71)	47.2 (8.53)	43.3 (11.43)	0.149[b]
	n (%)	n (%)	n (%)	
Body mass index (BMI)				
Normal or underweight	48 (82.8)	34 (89.5)	14 (70.0)	
Overweight/obese	10 (17.2)	4 (10.5)	6 (30.0)	0.078[c]
Parous				
Yes	10 (17.2)	6 (15.8)	4 (17.2)	0.724[c]
Type of delivery				
Normal	4 (40.0)	2 (33.3)	2 (50.0)	
Forceps/Vacuum	1 (10.0)	1 (16.7)	0 (0.0)	
C-section	5 (50.0)	3 (50.0)	2 (50.0)	0.659[d]
Constipation				
yes	9 (15.5)	7 (18.4)	2 (10.0)	0.476[c]
PFM training				
yes	13 (22.4)	8 (21.1)	5 (25.0)	0.750[c]

IQR, Interquartile range; PFM, pelvic floor muscles; [a]Mann-Whitney test; [b]*T* test for independent variables; [c]Fisher-exact test; [d]Likelihood ratio

Table 2 – Characteristics of the intensity of PA according to IPAQ in continent and incontinent women

	Total (n=58)	Continent (n=38)	Incontinent (n=20)	p-value
	median (IQR)	median (IQR)	median (IQR)	
MET, min/week	2428 (2778.0)	1840 (2752.0)	4199 (2505.0)	0.141[a]
	n (%)	n (%)	n (%)	
Physical activity level				
Moderate	21 (36.2)	18 (47.4)	3 (15.0)	
High	26 (44.8)	13 (34.2)	13 (65.0)	0.010[b]
Physical activity level				
Low	11 (19.0)	7 (18.4)	4 (20.0)	
Moderate	21 (36.2)	18 (47.4)	3 (15.0)	0.160[c]
Physical activity level				
Low	11 (19.0)	7 (18.4)	4 (20.0)	
High	26 (44.8)	13 (34.2)	13 (65.0)	0.447[b]

PA, physical activity; IPAQ, International Physical Activity Questionnaire; MET, metabolic equivalent task; IQR, Interquartile range; [a] Mann-Whitney test; [b] chi-square [test;] [c]Likelihood ratio

Regarding PA, significantly more SUI women than continent women were classified at a high PA level. SUI women reported higher values of total amount of PA (MET, min/week) in comparison with continent women, but the difference did not have statistical significance (Table 2).

None of the tested potential confounding variables influenced the results (results not reported).

Table 3 presents the association between PA and PFM variables. There was a positive correlation between PA and VRP in the continent women and a negative correlation among the SUI women (Table 3).

Table 3 – Correlation between physical activity intensity and pelvic floor muscle variables

	Continent n=38	Incontinent n=20
	Correlation (p-value)	Correlation (p-value)
PFM strength*MET-Min/week	-0.293 (0.074)	0.148 (0.534)
PFM endurance[a]*MET min/week	-0.240 (0.147)	0.348 (0.145)
VRP*MET-min/week	0.377 (0.020)	-0.458 (0.042)

PFM: pelvic floor muscle; VRP: vaginal resting pressure; MET: metabolic equivalent task; [a]Log-transformed variable; [b]Excluded one outlier in this analysis

DISCUSSION

The main finding of this study was the association between PA level and VRP. A weak positive association was found between PA level and VRP in continent women. Among the SUI women a moderate negative association was observed Regarding PFM strength and endurance, no associations with PA level were found in either of the two groups.

Two studies with a large sample of young women found that low-intensity PA [25] and low-impact activities [21] had a weak and negative association with SUI. Regarding more vigorous PA, results point in the opposite direction. On one hand, Hannestad et al. [25] found weak and non-significant associations between high intensity PA and SUI. On the other hand, Eliasson et al. [21] found that high-impact PA was an independent risk factor for UI.

Another study found that women who trained for competition had a 2.5 greater relative risk for having UI compared to inactive women [18].

In the present study the difference in PA levels between groups was found only when compared by categories. The SUI women reported a higher level of PA compared to the continent ones. This finding is in line with the suggestion that more strenuous PA may have a negative impact on UI [34]. It also can increase the odds of SUI later in life [35]. Since the number of young women engaged in strenuous PA is growing, there is a need to understand how higher levels of PA may impact the PFM. Hopefully, this study may help us to develop strategies to prevent future severe PFM dysfunctions.

The hypothesis that women who practice strenuous PA would have stronger PFM [6] is based on the finding that during increased IAP a pre-contraction of the PFM may occur in healthy women [16, 19, 40]. This may, theoretically strengthen the PFM.

In the present study continent women showed a weak positive association between PA and VRP, while in the SUI group a negative association was found.

The *Levator ani* muscles are constantly active, even at rest [15, 31, 40], which keeps the urogenital hiatus closed [3]. Women without PFM dysfunction counteract their IAP during common activities with an unconscious automatic increase in PFM activity [33, 40]. Therefore, it can be expected that physically active women activate their PFM more frequently and that this may increase the muscle tone, measured as a higher VRP. The positive association found in the present study in the continent group supports this assumption. However, since the association was weak and the clinical relevance can be questioned, the results should be interpreted with caution and further studies are warranted.

Interestingly, a reverse and moderate relation between PA and VRP was observed in SUI women. If there is no pre-contraction or a delay in the activation of the PFM during the raise in IAP, over time the connective tissue and muscles of the pelvic floor may be stretched and weakened, as postulated by Bø [6]. Thus, strenuous PA could potentially decrease the VRP. Middlekauff et al. [30], analyzing VRP in two different groups (practicing strenuous or non-strenuous exercise) found that post-exercise VRP significantly decreased in both groups, suggesting that the PFM may become fatigued, regardless of the exercise intensity. Ree et al. [39] found that MVC decreased after 90 min. of strenuous exercise in a group of women with SUI compared to after 90 min. of rest. However, whether strenuous exercise creates a long-term negative effect on VRP and whether this would be a risk factor for developing UI is not known.

Lower PFM resting tone has been related to pelvic organ prolapse [20]. However, until now there is limited knowledge on whether VRP reflects PFM tonus and continence status. Further studies are warranted.

It is well known that PFM plays an important role in the maintenance of continence [3], and different aspects of PFM function have been related to UI, such as lower PFM strength [11, 28, 36, 42] and endurance [12, 28, 32].

Different types of activity promote changes in IAP. Strenuous activities lead to a higher IAP compared to light activities [41]. In line with this finding, a positive association between strenuous PA and PFM strength could be expected. However, Borin et al. [11] reported contradictory results in a sample of young nulliparous women. The authors found that volleyball and basketball athletes had significantly lower PFM strength than non-athletes. Moreover, in the athletic group, the time spent in general strength training and volume of training (min/week) were factors associated with lower PFM strength. In contradiction, the results of the present study did not find any association between PFM strength or endurance and PA level. The same trend was reported in a recent study by Middlekauff et al. [30]. In a sample of young women with and without SUI, the authors found no significant differences in PFM strength between women who habitually performed strenuous exercise *vs* women who did not participate in regular heavy resistance or routine impact activity. A possible explanation for this finding could be that the training was of an insufficient amount and specificity to cause an effect [24]. General strength training needs to be of a sufficient amount and specificity to achieve a training effect, and the same applies to PFM training [5].

The present study did not find any association between PA and PFM strength or endurance. However, the sample size of our study could be insufficient to detect small differences. We have not been able to find studies that have assessed PFM endurance in relation to PA level in young women. Hence, more studies are needed on this association.

Strength and limitations

The strength of present study was the use of validated instruments and a standardized protocol including verbal instructions, and that assessments were conducted by an experienced physiotherapist. IPAQ is a subjective measure of PA. However, it has been found to be valid and robust and is widely used in sport science. PFM variables were assessed by manometry. The use of a Peritron manometer to assess PFM strength [23, 38] and endurance during a sustained 60% maximal contraction [38] has been demonstrated to be a reliable method. Limitations of the study are the sample size and that the sample included young healthy women with a large number of them being nulliparous. The results cannot therefore be generalized to other populations. The assessor was not blinded to continence status on some of the participants and this may have biased some of the assessments. Since PA and SUI were simultaneously assessed, no causative relationship could be assumed. Further studies are needed in order to identify a causal association between PA and SUI.

CONCLUSION

The present study revealed a weak positive association between PA level and VRP in continent women. In contrast, a moderate and negative association was found in women with SUI. Neither PFM strength nor PFM endurance were associated with PA level.

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CHAPTER III

Integrated Discussion

Integrated Discussion

This dissertation takes an epidemiological approach to female urinary incontinence (UI), pointing out its prevalence and potential risk factors in young Portuguese elite female athletes. Furthermore, it includes the relationship between UI and disordered eating. A second part explores the association between physical activity (PA) level and parameters of pelvic floor muscle (PFM) function in young women with and without SUI.

The results of the Original Studies indicate higher rates of UI among Portuguese female elite athletes when compared to non-athletes. High-level sports practice was identified as an independent risk factor for UI. The non-exercise related risk factors associated with UI in this population were constipation, family history of UI and history of urinary infection (Study I). Athletes with disordered eating presented higher odds of having UI (Study II). The level of PA seems to be associated with vaginal resting pressure (VRP). Weak associations were found between the continence *status* and the level of PA, with women with describing SUI showing a negative association. Nevertheless, no association was found between PA level and PFM strength or endurance (Study III).

Study I aimed to investigate the prevalence of UI and related risk factors in elite athletes. The majority were young, healthy, nulliparous, had a normal BMI and, no reported constipation. These epidemiological features, as well as the inclusion of a control group, allowed for better isolation of the impact of sports practice in UI. Aging, high BMI, constipation, parity and vaginal delivery are well-established risk factors for female SUI (Hampel et al., 2004; Liu, Wang, Huang, Wu & Wu, 2014; Milsom et al., 2016). Non-exercise-related risk factors such as family history of UI, history of urinary infection and constipation were associated with UI in Study I.

A genetic factor in the risk of development of SUI has been suggested. A large epidemiological survey found that women are more likely to develop SUI if their mothers or older sisters have the condition (Hannestad, Rortveit, Daltveit & Hunskaar, 2003). However, the authors were not able to identify a genetic component. Buchsbaum et al. (Buchsbaum, Duecy, Kerr, Huang & Guzick, 2005) investigated the prevalence of UI in parous women *vs.* their nulliparous sisters and found no difference in the severity or type of UI. A large survey, "The Swedish Twin Registry Study" showed that genetic effects account for 41% of the variation in liability for SUI. However, the influence of environmental factors was of the same magnitude (Altman, Forsman, Falconer & Lichtenstein, 2008). Some inherited connective tissues disorders such as Marfan syndrome and Ehlers-Danlos syndrome involve changes in normal collagen. High prevalence of SUI was reported in females with both syndromes, suggesting connective tissue disorders as an etiological factor for SUI (Carley & Schaffer, 2000). Collagen-rich tissues such as skin, ligaments and joints are involved, and a generalised joint hypermobility is a common feature (Shirley, DeMaio & Bodurtha, 2012). Some gymnastics modalities such as rhythmic gymnastics require hypermobile joints, and athletes with connective tissue disorders may be more likely to engaging in such sport disciplines. Hence, higher prevalence of SUI could be expected in gymnasts than in other sports modalities. Thyssen et al. (Thyssen, Clevin, Olesen & Lose, 2002) found in their study among elite athletes that gymnasts and dancers presented higher prevalence of SUI than ball games sports athletes. However, this trend was not found in Study I since acrobatic/rhythmic gymnastics, handball and basketball athletes presented similar prevalence rates. Such differences may be at least partially related with the fact that few gymnasts were included in our sample. Moreover, we have no data on potential connective tissue disorders from these athletes, neither on collagen levels from blood samples on which to base these conclusions. Although it is not possible to interfere with an individual's genetic heritage, this knowledge may help identify women at higher risk for UI.

In Study I, both constipation and recurrent urinary infections were associated with UI. Constipation has been identified as an independent risk factor for pelvic floor damage and UI, independently from age (Amselem et al., 2010). Chronic straining at stool may induce changes in the PFM by increasing stress and load over time (DeLancey, Kane Low, Miller, Patel & Tumbarello, 2008) and can contribute to UI (Amaral, Coutinho, Nelas, Chaves & Duarte, 2015). Recurrent urinary tract infections has been found to increase the risk for all types of UI (Parazzini, Chiaffarino, Lavezzari, Giambanco & Group, 2003) however, the underlying mechanism is not yet understood. Since constipation and recurrent urinary tract infections are modifiable risk factors, special attention should be given to athlete's reporting both conditions because they can have, at least theoretically, a negative cumulative effect. We were not able to identify previous studies addressing this subject in female athletes. Screening for these factors and implementing prophylactic measures could potentially benefit the continence *status*.

Regarding the high prevalence of SUI in athletes, our findings are consistent with previous studies (Almeida et al., 2016; Bø & Borgen, 2001; Fozzatti et al., 2012; Jácome, Oliveira, Marques & Sá-Couto, 2011; Vitton et al., 2011). Our results showed that sports practice at a high competition level is associated with higher odds for UI, as previously suggested (Da Roza, Brandão, Mascarenhas, Jorge & Duarte, 2015b). Hence, special attention should be addressed to elite athletes regarding UI.

Different rates of UI were found between sports modalities in Study I. The highest prevalence of SUI was found in trampoline athletes, which is consistent with previous studies (Almeida et al., 2016; Eliasson, Larsson & Mattsson, 2002; Eliasson, Edner & Mattsson, 2008; Vitton et al., 2011). Trampolining can induce greater impact on the pelvic floor when landing, and hence would be expected that urine leakage occurs in the landing phase. Eliasson et al. found that the leakage occurred mainly when doing double somersaults, contradicting this theory (Eliasson et al., 2002). Swimmers also perform twisting movements that promote abrupt increases in IAP due to contraction of the abdominal muscles (Cresswell, 1993). However, as the body is partially immersed in water, ground reaction forces have no impact on the pelvic floor whereas higher height jumps promote higher ground reaction forces

(Seegmiller & McCaw, 2003). Moreover, urine leakage may be more difficult to perceive in water.

Interestingly, the prevalence rate in elite horse riding athletes is among the lowest values obtained between the different sports modalities in women from our sample, in the line of what was previously found by Alanee et al. (Alanee, Heiner, Liu & Monga, 2009). A synergistic contraction of the striated urethral muscle and the PFM with the adductor muscles contraction could be hypothesised to have a strengthening effect on the PFM. At the best of our knowledge there are no studies on PFM strength in horseback riders, and no evidence to support that strengthening adductors muscles could improve PFM strength. A small study in healthy continent women investigated the effect of isometric contraction of hip adductors on PFM strength and found no immediate effect of the combined action on PFM contraction force (Amorim et al., 2017). Further studies are needed to clarify this hypothesis.

Another interesting finding is the disparity of prevalence rates between ball game sports such as volleyball and basketball, which are considered high impact sports (4.2% vs 24.1%, respectively), since high impact activities have been identified as an independent risk factor for UI in nulliparous women (Eliasson, Nordlander, Mattsson, Larson & Hammarström, 2004). Our results are not in line with other studies which found higher prevalence rates in volleyball players (Almeida et al., 2016). Few studies have evaluated PFM function on female athletes. Borin et al. compared PFM strength between volleyball, basketball and handball athletes to non-athletes, and found higher PFM strength among the non-athletes, as well as no differences between volleyball and basketball athletes (Borin, Nunes & Guirro, 2013). The difference in prevalence rates for different sports types may be explained by their potential distinctive impact on the pelvic floor. Also, non-sport related individual factors could be involved.

In Study I, more than one third of the incontinent athletes assumed UI as having implications with their sports performance. Despite that, few had reported the condition to a physician. It is surprising that this behaviour has been reported for over the past two decades (Nygaard, Thompson, Svengalis & Albright, 1994); Simeone et al., 2010; Thyssen et al., 2002). Once again it should be stressed that since these athletes compete at a high level, strategies to prevent and treat UI should be addressed. Educational programs for health care providers and coaches could provide added value. The view that UI is a natural part of sport practice may mean that athletes do not receive adequate advice. Identifying modifiable risk factors is of major relevance to developing preventative strategies.

The higher prevalence of disordered eating among athletes has been covered by several studies in the last decades (Borgen & Corbin, 1987;Bratland-Sanda & Sundgot-Borgen, 2013; Gomes, Martins & Silva, 2011; Kong & Harris, 2015; Krentz & Warschburger, 2011; Martinsen & Sundgot-Borgen, 2013; Monsma & Malina, 2004; Prather et al., 2016) with higher rates reported in those competing at an elite level (Kong & Harris, 2015), especially in sports that emphasise leanness and low body weight (Bratland-Sanda & Sundgot-Borgen, 2013). In contrast, results of Study II demonstrated no differences between athletes and controls, neither between athletes from leanness and non-leanness sports. Differences on the reported prevalence of disordered eating described in the literature ranging from 8.3% in soccer (Prather et al., 2016) up to 48.9% in athletes from leanness sports (Torstveit, Rosenvinge & Sundgot-Borgen, 2008). Besides different definitions (Bratland-Sanda & Sundgot-Borgen, 2013), training periods (on-off season), methodological issues (different sports, competitive level), screening methods (self-reported through questionnaires, clinical evaluation), investigators (coaches, researchers), age groups (Sundgot-Borgen & Torstveit, 2010) must be considered. Also psychological variables should be taken into consideration (Gomes et al., 2011), but this is not within the scope of our study.

In Study II, athletes with disordered eating presented higher odds of UI than women without disordered eating, even when adjusted for age, type of sport, smoking and alcohol intake, suggesting that disordered eating could be implicated in pelvic floor dysfunction. However, the underlying mechanism is unknown. In our study, besides the fact that no difference was found between athletes and non-athletes considering the EDE-Q global score, differences were observed in the restraint sub-scale. This addresses behaviour related to food restriction, and was higher in athletes than non-athletes and in athletes from leanness than non-leanness sports. Since athletes at high competition levels trained intensively and for long periods to enhance performance, disordered eating could lead to a lack of important macro and micronutrients for a proper muscle function during sport activity and recovery period. In fact, there are some studies showing inadequate nutrition (Gibson, Stuart-Hill, Martin & Gaul, 2011; Kabasakalis, Kalitsis, Tsalis & Mougios, 2007; Silva & Paiva, 2015) and energy restriction in elite athletes (Gibson et al., 2011; Heydenreich, Kayser, Schutz & Melzer, 2017; Melin et al., 2015; Silva & Paiva, 2015). Insufficient carbohydrates needed for glycogen replacement (glycogen depletion can lead to premature muscular fatigue) (Bogdanis, Veligekas, Selima, Christofi & Pafili, 2013; Gibson et al., 2011; Silva & Paiva, 2015), protein (required for tissue synthesis and repair) (Silva & Paiva, 2015) and, insufficient micronutrients such as iron and vitamin D which are essential for energy metabolism and the maintenance of body homeostasis (Bogdanis et al., 2013; Gibson et al., 2011). Vitamin D deficiency has been found to be associated with increased risk of pelvic floor disorder (Badalian & Rosenbaum, 2010) and due to the influence in skeletal muscle function (Ogan & Pritchett, 2013) a connection with PFM strength has been suggested (Parker-Autry, Burgio & Richter, 2012). However, knowledge regarding the impact of disordered eating on the pelvic floor is lacking. To avoid a potential negative impact of disordered eating on PFM function, it is important to detect, prevent and treat disordered eating among elite athletes.

The skeletal muscles of the pelvic floor play an important role in the urinary continence mechanism (Ashton-Miller, Howard & DeLancey, 2001, DeLancey, 1994). A normal PF function requires muscle strength, integrity of passive support structures and neuromuscular control (Grewara & McLean, 2008). Despite several reports of a high prevalence of SUI among women who actively exercise at both competition (Nygaard et al., 1994; Póswiata, Socha & Opara, 2014; Thyssen et al., 2002) and recreational levels (Bø, Bratland-Sanda & Sundgot-Borgen, 2011; McKenzie, Watson, Thompson & Briffa, 2016), the impact of PA level on variables of PFM function has been scarcely investigated. A recent review suggested that, contrary to a lack of PA and strenuous activities, moderate activity could have a protective effect for UI (Nygaard & Shaw, 2016). Some findings may support this assumption. The PFM are reflexively activated during different body movements involving the upper and lower limbs and trunk (Bø & Stien, 1994; Chmielewska et al., 2015; Sapsford & Hodges, 2001; Sjödahl , 2009) and in response to a rise in IAP (Shaw et al., 2014). Hence, a positive impact of PA on PFM function could be expected. On the other hand, if this unconscious activation does not occur at the right time and with sufficient force during strenuous activities, the PFM may be overstretched and impaired over time (Bø, 2004).

In Study III, we found an association between PA level and VRP in both continent (weak positive association) and women with SUI (moderate negative association). None of the potential confounding variables influenced the results. A large number of continent and SUI women included in the study were engaged in regular exercise and none were involved in high levels of competition. Hence, one can speculate that for elite athletes the degree of such an association could be higher. A lower PFM resting tone may provide less active support to the pelvic organs (Brækken, Majida, Engh & Bø, 2014) and consequently, more stress is imposed to the passive connective tissue structures of the pelvic floor, such as the endopelvic fascia and ligaments (Ashton-Miller et al., 2001). Over time, the passive structures may become over-distended and can lead to a lower position of the PFM in the pelvic cavity (DeLancey, 1994) compromising the ability of PFM contraction to compressed the urethra during increased IAP (DeLancey & Ashton–Miller, 2004).

No association was found between PA level and PFM strength and endurance, neither in continent nor SUI women. Hence, it can be hypothesised that increasing general PA could be insufficient to achieve a training effect on the PFM strength and endurance. In most sports, the PFM are not addressed. In Yoga and Pilates, women are told to contract their PFM but, to date, there is no scientific evidence that regimens other than PFM training are effective to treat UI (Bø, Mørkved, Frawley, & Sherburn, 2009). Moreover, Bø et al. (Bø et al., 2011) found a high prevalence rates of UI among Yoga and Pilates instructors.

The literature is scarce regarding the effect of PFM training on female athletes with SUI. Although few studies with small samples reported encouraging results (Da Roza et al., 2012; Ferreira et al., 2014; Rivalta et al., 2010), randomized clinical trials are needed.

Lower PFM strength has been found in athletes compared to non-athletes (Borin et al., 2013) and differences were found between athletes engaging on different sport modalities (Reis, Câmara, Santos & Dias, 2011). The effect of an exercise session on PFM function has been addressed in two studies. Middlekauff et al. (Middlekauff, Egger, Nygaard & Shaw, 2016) compared maximal vaginal descent, VRP and PFM strength between women who regularly perform strenuous and non-strenuous exercise. Before exercise, no differences between groups were found in any of the assessed PFM variables. After an exercise session of 15 min, an increase in vaginal descent and a decrease in VRP were observed in both groups, suggesting a loss of abdominal pelvic support. Ree et al. observed in a sample of SUI women a reduction in maximal voluntary contraction but not in PFM endurance and VRP after 90 min of strenuous physical activity, suggesting the development of PFM fatigue with exercise practice (Ree, Nygaard & Bø, 2007) and this can explain the report of urine leakage at the middle/at the end of training/competition (Caylet et al., 2006; Eliasson et al., 2002) as we also found in Study I, suggesting that the development of PFM endurance is required. In most studies, the samples comprised both continent and SUI women and the potential influence of continence status on the statistical analysis was not controlled, which may have biased the results. Moreover, since these studies have a cross-sectional design, no causative factor can be established between exercise practice and PFM function.

Previous studies have shown that SUI is associated with weakened PFM muscles. Lower PFM strength and endurance has been found in SUI women compared to continent women (Amaro, 2005; Burti, Hacad, Paulo Zambon, Polessi & Almeida, 2015; Madill & McLean, 2010; Thompson, O'Sullivan, Briffa & Neumann, 2006). However, potential confounders such as exercise were not controlled. In Study III a trend toward lower values of PFM strength and endurance was observed in women with SUI, although no significant differences were found. However, the results should be interpreted cautiously because the sample size is small and could be insufficient to detect small differences.

During voluntary PFM contraction, Shishido et al. observed that continent women developed higher pressure on the posterior side of the vagina than SUI women, suggesting that continent women have a more efficient *levator ani* muscle contraction (Shishido, Peng, Jones, Omata & Constantinou, 2008). The effect of a PFM contraction on increased urethral closure pressure has been demonstrated in women with and without SUI (Baessler, Miska, Draths & Schuessler, 2005; Dietz & Shek, 2012; Petros & Ulmsten, 1997) but the resulting effect of this contraction varies widely (Zubieta, Carr, Drake & Bø, 2016). Also, contraction may still not be fast enough to counteract the forces imposed by a repeated and high IAP during training, leading to urine leakage (Luginbuehl et al., 2015). Since we have no data on urethral pressure and no data regarding onset time of PFM activation in Study III, no comparisons can be drawn. Besides PFM strength, PFM position at an optimal level inside the pelvis may be crucial to maintain continence during strenuous activities. Lower PFM position both at rest and during a Valsalva manoeuvre has been shown in SUI women (Meyer, De Grandi, Schreyer & Caccia, 1996). Since PFM strength does not always correlate to continence status (Bø, Stien, Kulseng-Hanssen, & Kristofferson, 1994; Da Roza, Mascarenhas, Araujo, Trindade & Natal Jorge, 2013; Da Roza, Brandão, Oliveira, et al., 2015; Madill, Harvey & McLean, 2009; Morin, Bourbonnais, Gravel, Dumoulin & Lemieux, 2004; Verelst & Leivseth, 2004), it can be suggested that the resting position of the PFM should also be considered and evaluated to identify women potentially at risk for SUI.

In summary, our results found that UI is more frequent among elite athletes, in high impact sports and that disordered eating may increase the risk for UI. General PA was not associated with PFM strength or endurance, but seems to have a negative impact on VRP in SUI women. Hence, PFM training should be advised in elite athletes and incorporated into their training programs. Evaluation of PFM function variables would help to define the more appropriate individualised PFM training.

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CHAPTER IV

Conclusions

Conclusions

1) High-level sports activity was associated with higher odds for UI. Additionally, constipation, family history of UI and history of urinary infections were associated with UI.

2) No differences were found in the prevalence of disordered eating, neither between athletes and non-athletes nor between athletes from leanness and non-leanness sports. Athletes with disordered eating are at higher risk to develop UI than women without disordered eating.

3) General PA level seems to be associated with PFM resting tone but not with PFM strength or endurance. As opposed to continent women, in SUI women higher levels of PA seems to have a negative impact.

CHAPTER V

Future perspectives

Future perspectives

The high prevalence of overall UI and SUI found in our study among elite athletes, even within the youngest ones, emphasizes the need to develop strategies in order to promote continence in this population.

Health professionals should be aware of the potential exercise and non-exercise related risk factors to developing UI, especially among athletes at high competition levels. Hence, educational programs should be implemented at an early age in sport participation, especially for high impact sports.

The fact that most athletes do not mention the occurrence of UI unless specifically asked, and then some may deny the condition, means athletes should be actively screened for urine leakage for early identification of UI and to offer them timely treatment. Since among non-athletes the same trend was reported, educational programs could also be provided to young women at high-school level. The present study found that athletes with DE presented higher odds of UI than women without DE. Therefore, elite athletes should also be screened for altered eating behaviours.

Despite the growing interest in the topic of UI among athletes, there are few studies on the mechanisms of how sports activities may affect PFM function and the relation with UI development. In fact, the exact impact of different levels of PA and different sport types on the passive and active structures of the pelvic floor is still elusive, since studies in this area are scarce.

Although PFM training has been shown to be effective for treating SUI in women from the general population and is considered the first line treatment for SUI, there are few studies on the effect of PFMT for SUI in athletes. There is a need to develop adequate intervention, suitable for implementing jointly with regular sport training. The role of PFMT in teen athletes in order to prevent or minimize the occurrence of SUI is also an area where future research is needed. In this regard, we aim to develop an intervention plan among young female trampolinists to contribute to UI prevention.